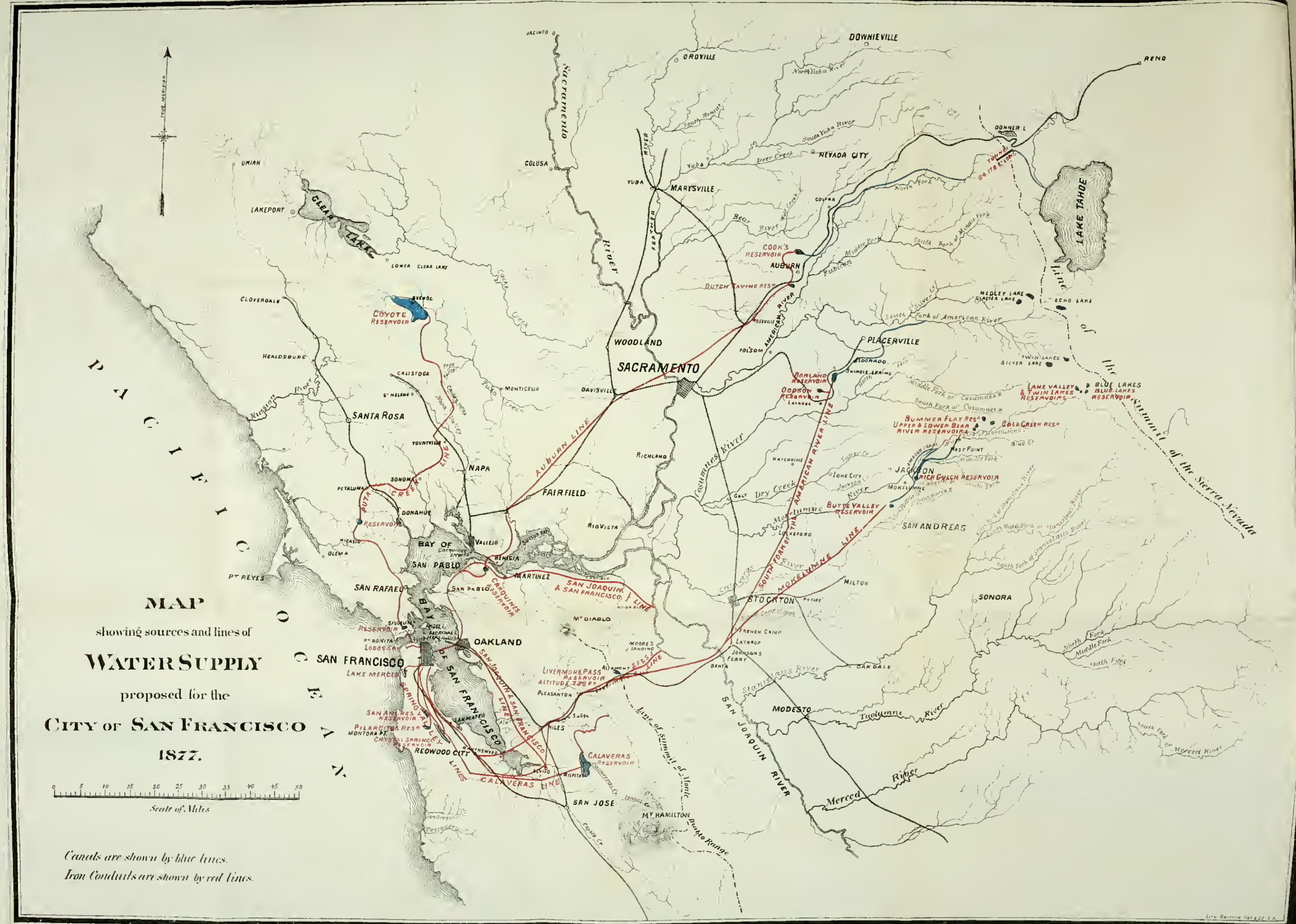
(" Rural Press " and " Scientific Press " Office,) 414 Clay Street.

1877.


MAP
showing sources and lines of
WATER SUPPLY
proposed for the
CITY OF SAN FRANCISCO
1877.
Scale of Miles
Canals are shown by blue lines.
Iron Conduits are shown by red lines.
PACIFIC OCEAN
SAN FRANCISCO
OAKLAND
SACRAMENTO
STOCKTON
SAN JOSE
LAKE TAHOE
CLEAR LAKE
BAY OF SAN PABLO
BAY OF SAN FRANCISCO
AUBURN LINE
PUTA CREEK LINE
SAN JOAQUIN & SAN FRANCISCO LINE
MOKELUMNE LINE
SOUTH FORK OF THE AMERICAN RIVER LINE
SPRING VALLEY LINES
CALAVERAS LINE
COYOTE RESERVOIR
CALAVERAS RESERVOIR
LIVERMORE PASS RESERVOIR
COOK'S RESERVOIR
DUTCH RAVINE RES.
BUTTE VALLEY RESERVOIR
RICH GULCH RESERVOIR
CARQUINES RESERVOIR
SAN JOAQUIN RIVER
Sacramento River
Line of the Summit of the Sierra Nevada
Line of Summit of Monte Diablo Range

REPORT

ON THE VARIOUS PROJECTS FOR THE

WATER SUPPLY

OF

SAN FRANCISCO, CAL.

MADE TO

THE MAYOR, THE AUDITOR, AND THE DISTRICT ATTORNEY,

CONSTITUTING

THE BOARD OF WATER COMMISSIONERS,

BY

G. H. MENDELL,

ENGINEER OF THE WATER COMMISSION.

SAN FRANCISCO:

Spaulding & Barto, Steam Book and Job Printers,

("Rural Press" and "Scientific Press" Office,) 414 Clay Street.

1877.

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The Mayor, the Auditor, the District Attorney—

Constituting the Board of Water Commissioners of the City of San Francisco:

Gentlemen—The Board of Water Commissioners and the undersigned, your Engineer, began the investigation of the problem of the Water Supply of San Francisco in May, 1876. In that month they visited Lake Merced and the Peninsula supplies, including in this term the storage reservoirs of the Spring Valley Company in San Mateo County, the Pescadero and San Gregorio, which discharge the drainage of the western slope of the Peninsula into the Pacific Ocean. and the Calaveras reservoir site. Clear Lake and Puta Creek, lying in the Coast Range to the north of the city, were also visited in May; and subsequently, as opportunity offered, the Commissioners extended their examinations, in succession, to Lake Tahoe; to the works and reservoir sites of the El Dorado Water and Deep Gravel Mining Company, on the South Fork of the American River; to the Rubicon River and Mount Gregory works; to the Mokelumne River and the works of the Amador Canal and Mining Company, including one of the sources of the Mokelumne, namely, the Blue Lakes; and to one of the reservoirs and some of the works of the South Yuba Canal Company, on the headwaters of the river of that name.

These examinations, made by wagon, on horseback, or afoot, as occasion required, in company with the representatives of the respective interests, carried the Commissioners over a considerable part of the drainage ground of the different sources of supply, and afforded them the opportunity of seeing much more ground than they actually traveled over, under circumstances which enabled them to carry away in their minds the general local features of the country, and gave them besides such specific information as could be obtained by observation and inquiry, or by the use of hand instruments, which alone could be carried or used on these reconnoissances. In actual area, these examinations embraced a large part of the State; in direction, they radiated half the way around the compass, beginning at the south, and going by way of the east to the north; and in distance, they ranged from Laguna Merced, which lies at the door of the city, to Lake Tahoe, which is, by any practicable route of travel or of conduit, more than 200 miles distant.

These examinations, extensive as they were, did not however comprise all

possible resources. Within the limits of distance which the most remote of these schemes involves, there are other sources of supply that might be included, but inasmuch as they have not been made the subject of special investigation, no mention is here made of them.

For most American cities, the source of supply lies patent before them, and discussion for them is confined to the means and scale and details with which the water shall be made available, or, if a second source is an alternative, the range of investigation is necessarily limited; but for San Francisco, our peculiar climate, the number of projects, the long routes proposed by many of these schemes, the variety and strongly marked features of the topography of the country, and some special difficulties of routes, combine to make the problem you have to solve one of unusual magnitude and complexity. To pick out from all these sources of supply the main characteristic features, to coördinate, compare and digest them, and from them to extract, as a result, the best means of supply for this city, is the problem before you, and this report is intended, although in an imperfect manner, to aid you to this conclusion. While the examinations of the Commissioners have taken a wide range, the actual surveys have, from motives of economy, so far been confined to the lines beginning in the Sierra Nevada, and inasmuch as such surveys are the only reliable bases for estimates of cost, this report will be devoted principally to those projects, in regard to which we have some accurate knowledge, derived either from our own or previous surveys.

THE SIERRA NEVADA AS A SOURCE OF WATER SUPPLY.

It would be difficult to imagine a drainage ground for city water supply, which would strike the eye in a more favorable way than do the western flanks of the Sierra Nevada, from a lower limit in altitude of three or four thousand feet, to the summit ridge which lies at a height varying from 7,000 to 9,000 feet, overtopped at intervals by snowy peaks, which rise two or three thousand feet above the general level of the dividing ridge.

Between these limits of height are the areas of maximum rainfall, which is deposited on the higher levels in the form of snow, attaining at times great depth. These high mountain ranges are the condensers, which extract from the southerly winds the load of moisture, which they bring from the regions of maximum evaporation in the Pacific Ocean. This burden of moisture is almost entirely unloaded in these regions, and over the land lying to the seaward, comparatively little being left for deposit on the plains to the east. The precipitation on the eastern slopes may be likened to the overflow or spilling of the clouds, often considerable immediately on the eastern face, but rapidly diminishing to an insignificant quantity in the distance of a few miles. On the western slope we find a precipitation, which increases with the altitude and attains a maximum at about 5,000 feet elevation, preserving this maximum to as high a point as systematic observation has been carried, which is the summit on the Central Pacific Railroad, at an altitude of 7,000 feet.

The only systematic observations of precipitation along the whole profile of the Sierra, which are known to exist, are those kept at the stations of the Central Pacific Railroad. Their series of observations now comprises six years, and although they are limited in time and confined to a particular line, and although we cannot be sure that the future or different topography will not, or might not vary these results in some considerable degree, we are, from the want of more extensive knowledge, confined in our investigations to these.

Within this period of six years, twenty-eight feet of snow have fallen in one season at the Summit. Reducing snow to rain, the lowest fall at the Summit was 37.77 in., which occurred in the winter of 1870–71, and the greatest was 73 in., in the winter of 1873–74. The three largest falls were 73 in., 70 in., and 61 in.; the lowest, 37¾ in., 39 in., and 49 in. The aggregate fall at Emigrant Gap, altitude 5,300 feet, for six years, was 318 in.; at the Summit for the same time it was 330 in. The fall at Emigrant Gap was in 1872–73 considerably in excess of that at the Summit.

Starting from the Sacramento Valley, we ascend into regions of increasing rainfall. At Auburn, 1,300 feet above the sea, the rainfall is year after year quite 50 per cent. greater than that at Rocklin, 270 feet high; while Colfax, 2,450 feet high, has in every year at least 33 per cent. more than Auburn, and more than double that at Rocklin. At Colfax the fall is in some years equal to that at the Summit; the lowest ratio is 75 per cent., and the average, 83 per cent. At Alta, elevation 3,600 feet, the rainfall is, in different years, both greater and less than that at Colfax.

On the eastern slope at Truckee, altitude 5,500 feet, the average fall is 54 per cent., the minimum 43, and the maximum 67 per cent. of the fall at the Summit, while at Reno, altitude 4,500 feet, the fall is never as much as 10 per cent. of the fall at the Summit. The lowest fall of which we have a record is in the winter of 1870–71, in which there were—

At the Summit	37.77 inches.
At Emigrant Gap	35.96 inches.
At Colfax	31.07 inches.
At Truckee	16.16 inches.

For any calculations now made, looking to the capacity of a water shed in the Sierra Nevada, these figures, being the lowest known to this date, should be used.

The physical aspect of the highest regions of the Sierra is that of immense peaks and flanks of granite mountains, the summits denuded, bald and bare when free of snow, the less exposed tops and sides supporting, in crevices, a scanty vegetation, the most conspicuous feature of which is the growth of stunted trees, half starved for want of sustenance, and almost overwhelmed in constant struggle with the elements for life.

Here and there, mingled or alternating with the granite, or perhaps overlying it, are picturesque masses of basaltic rocks. Scarcely any organic life,

except the struggling vegetation, is visible in these higher altitudes. Descending to a lower level, perhaps two thousand feet below, the landscape opens out into amphitheatres, in which lakes and meadows, once lakes themselves, afford a variety of scenery, less grand and softer to the eye. We here enter upon a region which is very sparsely inhabited for a part of the year. Cattle and sheep are driven here from the plains below for the sake of the pasturage, which these meadows afford for three or four months in the year. These flocks and herds return to the plains when the first premonitory storms visit the mountains. This second level is timbered with groves of fir and tamarack. Descending still lower, we enter upon the sugar pine belt, and following down the ridges we find them closely covered on tops and flanks by magnificent forests, of which by far the greater part are coniferous trees, with here and there an oak. The flanks of these ridges are deeply eroded by the small streams, which, at short intervals of distance, on either side pursue nearly parallel or converging paths, uniting in the main streams which lie perhaps 2,000 feet below. The main streams pursue nearly parallel paths, and uniting in the lower foot-hills they form the rivers which have distinctive names on our maps. The routes of these streams are what would be imagined. They fall over rocky channels with precipitous descent, at one season boiling torrents, at another gentle rivulets.

The geological character which we observed in the higher regions is preserved until we enter the mining district, which covers perhaps the lower third of the flanks of the mountains. Here we encounter the gold bearing slates, which lie with upturned edges, and the granite gradually disappears. Here and there, at rare intervals, in small quantities occur calcareous deposits, but generally the geological structure ensures a soft water. Above the mining districts there is no influence to injure the character of the water. There are few or no inhabitants, little or no cultivation, and the influences which exist are favorable. The rapid course of the streams over uneven beds serves to aerate the water derived from the melting snow.

No constructions, except reservoirs, are proposed for any of the schemes in these upper and rugged regions. Up to the eastern limit of the mining district, the water is to remain in natural channels. On the borders of this region, and below the line of severe snowfall, are to be found the points at which canals should tap the rivers to carry supplies for the city.

The Lakes and Meadows of the upper regions are an important factor in the problem of large supply, and on this account they require more than passing notice.

These lakes lie nestled in greater or less profusion all along the range, as far as the Commissioners' examinations extended, with areas of a few acres to some hundreds, in amphitheatres surrounded by peaks and ridges a thousand or more feet above them, and generally with narrow outlets, which permit them to be dammed by inexpensive constructions. This last named fact, and the further circumstance that their surfaces are level and often pieced out by meadows scarce above their own level, (which gives them great capacity

per foot in height of dam,) make them extremely valuable as storage reservoirs. A further important advantage is, that they lie in regions of maximum precipitation. A disadvantage is, that they are practically inaccessible in the winter and spring, on account of snow.

The lakes are doubtless undergoing a process of diminution, both in depth and in area. They are the resting places of the granitic detritus, eroded from the mountains above by the small streams which supply them, and this action, in time, supplemented by the aid of frost must, it is believed, bring them to the condition of the meadows, which in some cases in fact surround them.

The water which they store will come from the melting of the snow above them. During the winter, and perhaps as late as April or May, the snow is itself the reservoir, but about this time it begins to pass away, and continues to do so in increasing degree until a period, sometimes earlier and sometimes later, generally in June, when the supply gradually diminishes, reaching small limits in August. The duration of the melting period, however, varies very much, and depends largely upon the quantity of snow to be melted.

In the early part of August, the Commissioners found large areas of snow at and above the altitude of 7,500 feet, on the headwaters of the branches of the American and Mokelumne rivers. The snowfall for the previous winter had, however, been large. At Silver Lake the fall was stated to be twenty-one feet. In consequence of this fact, the rivers kept up to an unusual degree late in the summer. In the early part of August, 1876, the Rubicon, Mokelumne, and the South Fork of the American flowed about equal quantities, being, as nearly as could be estimated, fully 300 millions of gallons per day.

The general state of flow in the rivers may be described as follows, namely: In November, as a rule, they take up a large flow, which is continued through the winter months by the rain falling on the lower flanks of the mountains. The flow is kept up by the progressive melting of snow in May, June, and July, and to a less degree in August. In September and October they are in the lowest stage.

So far as mere quantity of water is concerned, irrespective of the rate at which it is delivered to and carried off by the principal water courses, we may be assured that an area of 200 square miles or less, in the altitude at and above 2,500 feet, will drain off in the direct year known to our observations more than enough to satisfy the largest prospective demand of the city.

This consideration of quantity, although of essential importance, is not, as might appear at first glance, the whole question. The quantity being sufficient, we would wish further to have it delivered to our canals at an uniform daily rate. We have for a large part of the year much more passing than we could use, and at times we may find less than we require. We are indeed, in this investigation, less concerned about the high stages of the rivers, than we are about their minimum discharge, and the length of time during which the supply in the rivers will be less than the prospective draft to be made upon them. We are not without some information on these points, although we

are not possessed of all that it is desirable to know. Such information as we have indicates that it will not be safe to rely upon the flowage alone of the rivers under consideration, but it does not inform us altogether as to the degree or amount of supplementary supply to be provided.

In October, 1874, Mr. Scowden noted that the Mokelumne flowed only thirty-two millions of gallons per day.

In September, 1876, the flow of the same river past the head of the Amador Canal was only twenty-five millions of gallons per day.

The river is said to have been lower in September, 1875, than known for twelve years. It then carried what was estimated to be about fourteen millions of gallons a day.

On December 30, 1876, the quantity flowing at the head of the Amador Canal was sixty-two millions of gallons. A day or two subsequently, the flow past the head of the new canal of the El Dorado Company, at an altitude of 4,000 feet, was only twenty millions of gallons a day, and on the same river, at the mouth of Silver Creek, the flow was seventy-three millions of gallons per day.

The autumn flow of the South Fork of the American becomes very small at times, whether as low as just stated for the Mokelumne is not known.

The flow of both rivers last December is doubtless unusually low, for as has already been stated the rivers at this time are full in ordinary years.

This information, meagre as it is, is nevertheless very important, for it tells us that even with a demand of 20 millions of gallons per day, there are times, of longer or shorter duration, in which the rivers could not honor it.

While we may then conclude for the rivers we have mentioned, that it would be unsafe to rely upon the natural flowage, even for the smallest quantity proposed to be taken for the city supply, we are not informed fully as to the length of time in which to expect the minimum flow. We know enough, however, to assure us of the necessity of providing storage water in the mountains, *pari passu* with the construction of even the smallest conduit, that it would be expedient to build.

In the absence of full information on these necessary points, it will be the plainest dictate of prudence to make the storage capacity on a scale, which shall provide for a contingency, more unfavorable both in quantity and in time, than any previously known to exist.

It will, however, be plain that while the preparation of storage facilities goes on with the construction of the conduit, it will only be necessary that it should keep pace with, and bear a relation to the capacity of the conduit; and that it will not be necessary at first to provide the storage which would be required, when the city draws the maximum supply, say 100,000,000 gallons. It will at first be necessary only to store enough to make up the deficiency of the river, for an assumed number of days, in the supply of 20 or 30 millions of gallons per day. Afterwards, when the draft made by the city shall be 60 or more millions, the storage capacity will require a corresponding increase. The interval of time, elapsing before the increased de-

mand is made, will supply the information upon which the increase will depend, and this increase can then be proportioned to the well known requirements of the case.

The foregoing discussion places the mountain lakes and meadows in an important relation to the Sierra projects.

It may further be stated, that the probable drainage areas, as they are gathered from our best maps—which, however, as they are not based on trigonometrical surveys, must be accepted with caution—are, for the Mokelumne above the head of the Amador Canal, about 300 square miles; and the same, or something less, for the area above the head of the large canal, on the south fork of the American. Dividing the minimum known daily flowage by the area in square miles, we find the drainage to be as low as 50,000 gallons per square mile for one day. The topographical and geological structures of the drainage ground are largely responsible for this very low minimum. The first, because the steep declivities carry the water off quickly; and the second because the granitic rocks do not permit the water to percolate to any considerable extent. Some sandstones and limestone formations permit large quantities of water to percolate below the surface, which, pursuing a slow and devious course underneath, reappear at lower levels in the form of springs, and thus aid in holding back the flood waters, and in distributing the supply over months instead of days. These formations are, however, almost entirely wanting in the Sierra, and the geological structure favors the efforts of the steep declivities to deliver their load of water, in the least possible time, to the drainage lines below.

What has been ascertained in regard to the minimum flowage of the Mokelumne and the South Fork of the American, may be fairly assumed to apply to other drainage areas of equal extent, along the middle belt of the Sierra. At least, no circumstance of geological or of topographical character is known, which places the watersheds referred to in disadvantageous comparison with any other in the same region.

Here we may note the conservative influence of snow. It may be said, in a certain sense, to prolong the rainy season until June or later, by distributing the discharge over this long interval. It also serves to protect the plains below from flood. If the deposit in these high altitudes were in the form of rain instead of snow, our streams would for a few months be uncontrollable torrents, devastating the valleys each successive winter, and for the remainder of the year, owing to the geological conditions, merely dry beds.

The course of this discussion requires us to assume a proportion of the snow or rain falling on given areas, which can be saved for storage in the various reservoirs. We are compelled, from want of specific information applying to different high localities, to use the known fall at the Summit; and for the proportion of water saved by storage, we look to the results of measurements in other parts of the world. It is not to be denied that we here enter upon a region of speculation, as distinguished from safe induction, and some memorable misfortunes to water works have occurred, from the

assumption of too high a co-efficient for impounded water. Something, however, must be assumed as a basis for reasoning and comparison, and the co-efficient, which is adopted for the computations which follow, is 70 per cent. In the year 1870–71, there was at the Summit a fall of 38 inches, seventy per cent. of this being 27 inches, very nearly. It is, therefore, assumed that in this year there was drained from every square foot of area a quantity of water, which, collected in one body, would have been 27 inches deep.

This co-efficient has a special importance only in the years of minimum rainfall.

It has already been remarked that the slopes of the higher Sierra are steep, and that their geological structure is chiefly granitic. The peaks and ridges have scanty soil, and in great part, the drainage ground is made up of cliffs and fields of smooth and naked granite. These features of the country will, perhaps, justify an assumption of as high a co-efficient as is afforded by any other drainage ground, on which observations have been made.

The following records of observations in Europe illustrate the highest result there obtained:

Loch Katrine District, area 71.6 sq. miles (precipitous)	80 per cent.
Loch Lubnaig, area 69.7 sq. miles (precipitous)	75 per cent.
Brockburn District, near Glasgow	79 per cent.
River Bann and Lough Neagh, Ireland	78 per cent.

These districts are all mountainous, and resemble the Sierra in topographical features, more nearly than any other regions of which we have authentic records. It is preferred, however, to assume a lower co-efficient than has been deduced for these districts. In doing so, we make some allowance for evaporation.

Leaving now the more general aspects, which are common to the Sierra Nevada sources of supply, we may proceed to notice the different schemes in a more specific way.

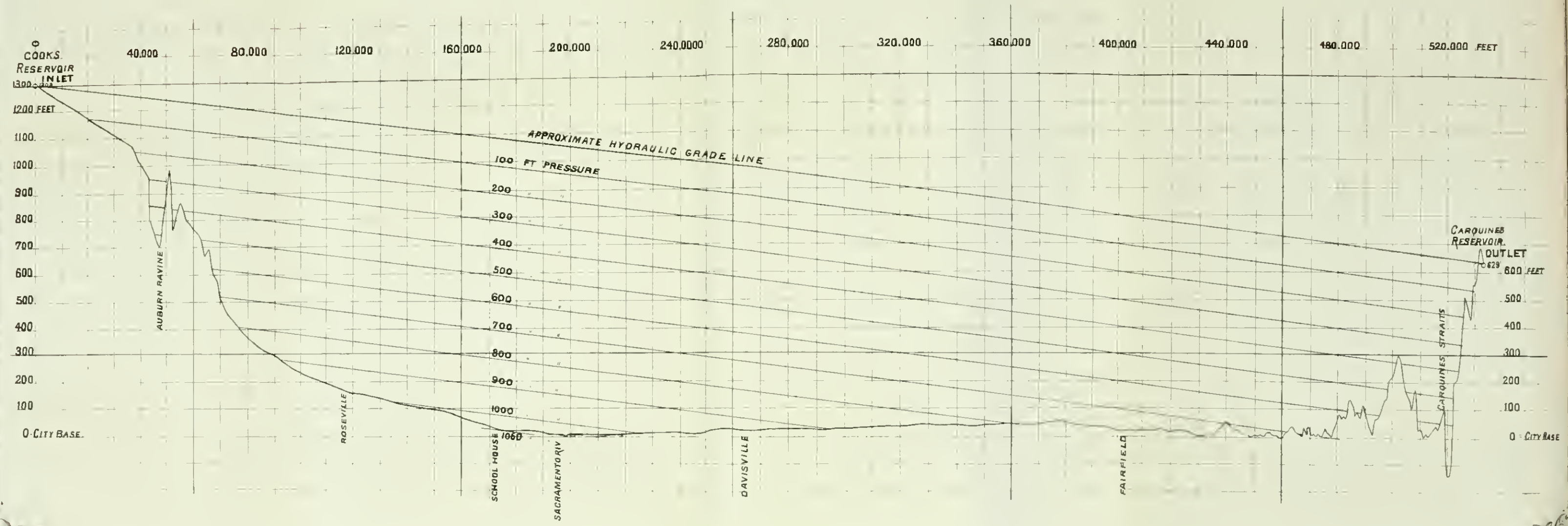
LAKE TAHOE.

This lake lies partly in California and partly in Nevada. It is, however, on the eastern slope of the Sierra Nevada, and its altitude above the sea is something over 6,200 feet. Its greatest length is 22 miles, and the greatest width 12 miles. Its area is 192 square miles, more or less, and its drainage basin, including in this its own area, is 500 square miles. These dimensions are taken from the published map, which is the only definite and available source of information. The lake is stated to have a depth of 1.500 feet. It is never frozen over, and this fact is probably due to the great depth.

The lake lies between two high and nearly parallel mountain ranges, one to the east and the other to the west. The amphitheatre is completed by other mountains, receding to the south, between which and the lake lies the valley

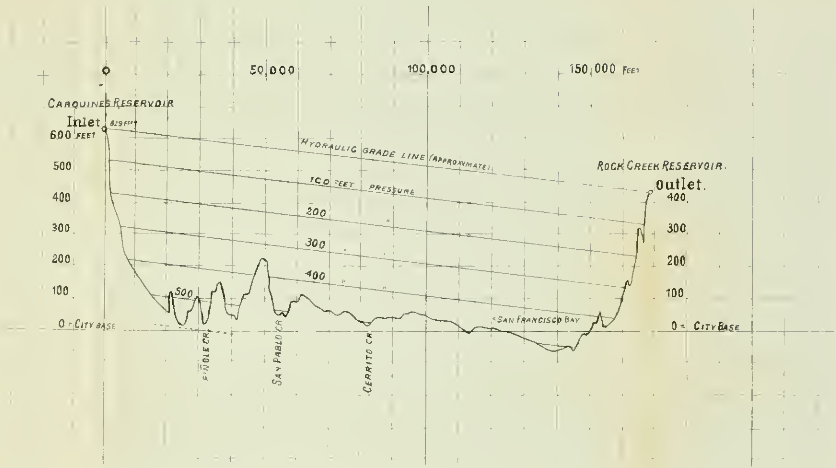
PROFILE of line of Inverted Syphon from the foot hills of the Sierra Nevada near Auburn, to Carquines Reservoir

Total length of Pipe 533,301 feet. By survey of 1876 to Fairfield, thence by T.R. Scowden's Survey. Total fall 674 feet



By survey of 1876.

Scale 1 inch to 40,000 feet



of the little Truckee river, the largest of its affluents. Smaller streams contribute their quota, derived from the mountains on either side, which rise three or four thousand feet. The only outlet to the lake is the Truckee River, which carries the surplus waters out upon the dry plains of Nevada. The altitude of the lake and of its drainage ground, to say nothing of the rugged character of the latter, forbids settlement or cultivation, and we may be certain that these hills will remain as nature makes and keeps them, except that the timber with which they are covered will diminish year by year, under the demand of the mining industry of Virginia City. There can then be no human operations by which the water can be discolored or injured.

While the character of the drainage ground, which is that already described as belonging to the higher regions of the Sierra, assures the quality of the water, its area and altitude fully assure its quantity.

To take 100 millions of gallons per day, for every day in the year, would lower the level of the lake less than one foot, disregarding evaporation and drainage.

To restore one foot to the lake would require the drainage basin to deliver less than five inches of rain. The lowest fall of which we have any record at Truckee, a few miles distant, and 600 feet below the latter, is 16 inches.

The dam at the lake raises the water six feet, or thereabouts, above the lowest level, and will serve to distribute the excess of one winter over the next year, should its accumulation prove below the average.

This lake is to be regarded as a reservoir, which can always be relied upon to furnish any desired amount of water, and its relative value, as compared with other projects having their source of supply in similar regions, is to be studied in the light of the expense necessary to make the reservoir available for our purposes. The dam at the outlet of the Truckee is made of timber, and it will be inexpensive to replace, when it becomes necessary. It is supplied with gates, by which the flowage of the Truckee River can be regulated. A large but unknown quantity of water is now, and will be required for the service of the mills along the river.

It is proposed to take the water for city supply from the Truckee River, 3¾ miles below the lake. At this point there is a dam, by means of which the water can be diverted into a canal, which will deliver it, in a length of 15 miles, at the mouth of the tunnel to be constructed through the Sierra Nevada.

This tunnel will be 24,172 feet in length, of which, 18,496 feet will require to be excavated from two points, one at each end, the height of the mountain being considered, over this distance, as too great to admit the use of intermediate shafts. The remaining part of the tunnel, 5,676 feet in length, can be excavated in convenient intervals, by shafts about 100 feet deep. The tunnel is intended to be cylindrical, with a diameter of eight feet. The western end of the tunnel will be near Soda Springs, and its floor at this point will be 6,143 feet above the sea.

Here the water will be discharged into the south branch of the North Fork

of the American, from which it will be again taken out by a canal, twelve miles below. This canal is estimated to be 60 miles long or thereabouts, and it will terminate at the reservoir north of Auburn.

The part of this line which has been surveyed, is the Canal line on the east side of the mountains, and the profile of the tunnel. The Canal line on the west side has not been surveyed, and its length is merely estimated.

The North Fork of the American will give a sufficient supply of water for a large part of the year, and it is only when this supply becomes deficient, that it will be necessary to draw upon the reservoir of the lake.

The works, then, which may be regarded as necessary to make the reservoir practicable for use, are—the 15 miles of canal on the eastern side, and the tunnel through the mountains. When these parts of the work are constructed, Lake Tahoe, as a source of supply, will be placed in a position of direct equality with another scheme, which should propose to supply the city from the canal head on the North Fork of the American, having at its command abundant reservoir capacity in the mountains above that point. If such a project should require as large a sum to provide and fill abundant and safe reservoir capacity, as it would cost to execute the items of construction last mentioned, then the two schemes would, for our purposes, be upon an equality, the element of time alone being unconsidered.

Lake Tahoe is not only an abundant reservoir, but it is preëminently a safe reservoir. The dam, as has been remarked, raises the water only six feet, and therefore it is not exposed to danger.

It remains to say, that the estimate of the cost of these items is, by the statement of the President of the Lake Tahoe and San Francisco Water Company, $1,741,960, ten per cent. contingency being added, which sum is to be increased by $300,000 for franchise, lands, etc., making a total of $2,041,960.

The route from the Auburn reservoir to this city would be common to the different projects, coming from Lake Tahoe, North Fork of the American, and from the South Yuba.

The Company require five years in which to bring the water to Auburn.

It may be remarked that such long tunnels as this, 3½ miles between working points, are liable to great contingencies in time and expense, arising from our want of positive knowledge of the material which we will have to encounter. In this case we may feel some reasonable confidence of encountering a long line of granite. There are, however, some reasons for supposing that a part of the line will be in material more easily worked than granite. Whether this material will bring inconveniences to counterbalance, or more than counterbalance the advantage of easy working, we can not now say.

In the present state of our knowledge, and for present purposes, we may take the estimate and offer, made to you by the Company to construct this tunnel, as an element of comparison.

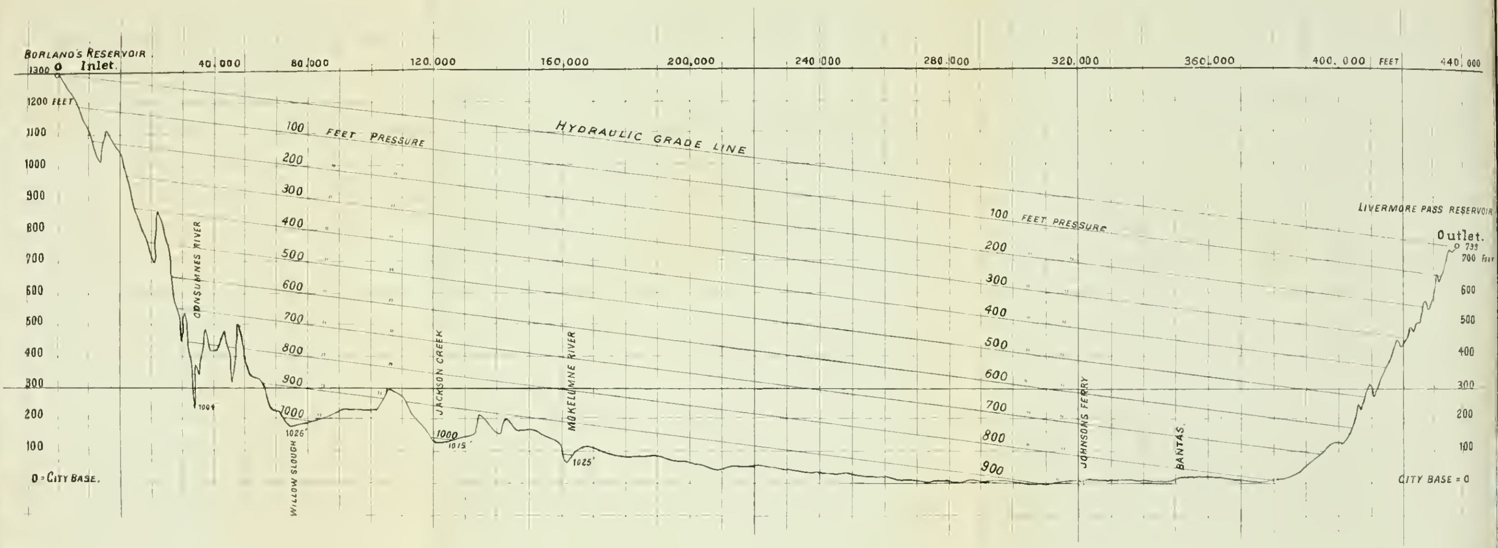
The tunnel site has the advantage of easy communication by rail with sources of supply.

The canal head, on the west side of the mountain, will be at an altitude,

PROFILE of line of Inverted Syphon from foot hills of the Sierra Nevada near Latrobe to Livermore Pass

Total length of Pipe 434,855 feet. Total fall 561 feet.

By survey of 1876.



Lith. Britton, Rey & Co. S.F.

as near as we can now fix it, of about 4,000 feet above the sea. This high altitude for a canal is objectionable, on account of exposure to snow, which is liable to injure and obstruct the canal.

THE EL DORADO PROJECT.

In this project it is proposed to take the water from the South Fork of the American River, at an altitude of about 2,500 or 2,600 feet. This altitude is very suitable, more so than one much higher, for this level is nearly free from snow, which at higher elevations would be liable to create obstructions to the flow of water in the canal, and indeed to injure it, during a period of a month or two in severe winters. Beginning at this point, the canal would end at the Borland reservoir, which lies between Latrobe and Shingle Springs, a length of route of 45 miles. An iron conduit would carry the water to San Francisco by way of Livermore Pass.

The drainage area above the head of the canal and tributary to the river at that point, is between 200 and 300 square miles. This area for supply purposes will be practically increased by a canal, now nearly finished, which is to carry a large quantity of water from Silver Creek, which is a large tributary of the South Fork, joining it, however, below the proposed canal. The canal will discharge into the South Fork above the point of diversion of the city supply.

The river and its principal branches have their sources in the highest mountains in this part of the Sierra. The Rubicon and the Mokelumne adjoin it in their sources on either side, and are characterized by the same general features, which are those previously described as common to the higher regions of the Sierra.

Within this drainage ground are included some very high peaks, among which may be mentioned Roundtop, Pyramid and Elephant peaks, all of which had fields of snow in August.

A distinguishing feature of this drainage basin is the number of lakes of considerable area, lying at elevations of 7,000 feet or higher. The principal lakes are known by name, as follows: Silver Lake, which is one of the sources of Alpine Creek, a large tributary which enters the river above the canal; Glacier Lakes, at the head of Silver Creek, before mentioned; the Medley Lakes, a large network of lakes, separated by peninsulas of low-lying rock, draining directly into the South Fork; Twin Lakes, near Silver Lake; and Echo Lake, which has hitherto discharged its overflow into Lake Tahoe, but which has been, in part, diverted to the Western slope. There are other reservoir sites, which are mentioned in the proposition of the El Dorado Water and Deep Gravel Mining Company, which it is not necessary to mention in this paper.

The Lakes above mentioned, except Echo Lake, are admirably suited for storage at small expense. The Company propose a dam for Echo Lake, 400 feet long at the base and 75 feet high; but none of the other Lakes mentioned will require dams more than 30 feet in height, and some not even so much.

SILVER LAKE has now a dam 20 feet in height. It is built of timber cribs filled with stone. It is 160 feet long on top, and could readily be raised 10 feet.

The present area overflowed is estimated at about 1,800 acres. It may, however, be more, and it would be materially increased by raising the dam 10 feet.

Here a remark may be required, in explanation of the discrepancies which may be found to exist between the estimates of area and quantity, contained in this report and those that are offered in the various propositions submitted to you.

Where the estimates result from actual survey, they can be accepted with confidence, but in the cases where they are given on the mere judgment of individuals, who have walked or ridden over the ground, they are decidedly open to question, and it has been preferred in this report to place them at what, from the best means of information, whether by inquiry or observation, appears to be a limit safe from exaggeration and below that indicated by appearance or probability. These areas of reservoir and of drainage basin could, in many cases, be well taken in by the eye. In such instances an estimate was made. In this mode of procedure it is perhaps possible to do some injustice, but under the circumstances it is a safe course.

SILVER LAKE is assumed to have a drainage area of 30 square miles, and as an illustration of what goes before, it may be stated that the estimate of an intelligent man, who has been for some years familiar with the ground, is 64 square miles. A drainage of 16 inches from 30 square miles would fill this reservoir as it now exists, and we can hardly doubt that, if increased in depth 10 feet by an increase of height of dam, it would yet be filled or nearly filled each year, assuming the minimum fall, as recorded at the Summit Station, to apply here.

Placing the area at 2,000 acres and depth 25 feet, the storage capacity would be, say 16,000 millions of gallons, and the minimum amount we expect in any year is 12,500 millions of gallons, which is 2¼ feet drained off the land.

The GLACIER LAKES lie at the head of Silver Creek. They are not dammed. The present area of the Lakes is between 200 and 300 acres. They are bordered by an extensive meadow, over which a dam 20 feet high would throw the water, to cover in all about 1,500 acres. The drainage area is about 12 square miles. The Lakes are over 7,000 feet high, and the mountains rise above them several thousand feet. There was considerable snow on these mountains in the early part of August. A stream was discharging six millions of gallons daily from the Lakes.

Inasmuch as these Lakes are on the headwaters of Silver Creek, which empties into the South Fork of the American below the proposed canal head, their storage can only be made available for city supply by means of the canal, which has already been alluded to as nearly completed.

The minimum drainage over this 12 square miles area can hardly be so little

as 5,000 millions of gallons. It is hardly to be expected that a reservoir of 1,508 acres, to 20 feet depth, requiring 10,000 millions of gallons, could be filled every year. This would require rather more than five feet of water to be drained off the land.

The Medley Lakes consist of a network of water spaces, covering in all about six square miles, half of which is rock rising a little above the level of the Lakes. The drainage area is 10 or 12 square miles, half being high mountains. A dam 20 feet high, 20 feet long on the bottom and 60 feet long on top, would make the whole area—3,600 acres—a reservoir. A higher dam would give the water height enough to drain over into Lake Tahoe. We could hardly expect this reservoir, holding perhaps 20,000 millions of gallons, to be filled in any but very exceptional years. It would require eight feet of water to be drained from its drainage basin, estimated at 12 square miles. The minimum may be taken, as in the case of an equal area tributary to the Glacier Lakes, to be not less than 5,000 millions of gallons.

These Lakes now drain directly into the South Fork, and the storage would be available for our supply.

The Twin Lakes have a drainage area of 10 or perhaps 15 square miles, and their storage may be placed at the minimum of 6,000 millions of gallons.

Leaving out of mention other Lakes and reservoir sites, we have already a minimum of storage of 23,500 millions of gallons, which is more than 100 millions a day for 200 days in each year. This is made up as follows:

Silver Lake	12,500 millions.
Medley Lakes	5,000 millions.
Twin Lakes	6,000 millions.
Total	23,500 millions.

This calculation leaves out the Glacier Lakes, which require an artificial channel to make them available.

With this summary, and remembering that we have in reserve Echo Lake and other reservoir sites, and that we may increase our supply by holding over in the reservoirs already mentioned—which will have a capacity much beyond our assumed minimum—the excess of one winter to make up for the deficiency of another, we may dismiss this branch of the subject without further inquiry, and with the assurance that the supply is abundant for all possible needs. The daily flow of the river, from an area of 200 or 300 square miles, in connection with the storage, will always be found adequate for any needed supply.

It is important to remember that the dams required to form these reservoirs are low, and on that account little exposed to danger, and that their construction, as dams are made in these regions, is quite inexpensive. The character of constructions used for storage in the mountains, now being generally timber cribs filled with stone, or of dry stone masonry, is not such as the city would ultimately require; but such constructions as exist would serve a good tempo-

rary purpose, until the city is prepared to build in another and permanent way.

Silver Lake is the only lake in this series which is dammed. In its present state the Lake is available as a reservoir, and if reserved for the supply of the city, it is abundant for a number of years to come. When the necessity for further storage approaches, Twin Lakes might be dammed with a permanent dam of masonry, and as opportunity offered or necessity required, the other reservoirs could be created in a similar way. At some future time it would be necessary to replace the crib dam at Silver Lake. This dam is 160 feet long on top, and has a height of 20 feet. It is provided with gates to regulate the discharge.

It will be apparent that this drainage basin can afford by its direct flowage, supplemented by storage, a much greater supply of water than will be required by the city. The excess over the latter limit can be used in future, as it is used now, for mining purposes. The company have diverted the water from the river, at a point about 4,000 feet above the sea, into a canal intended to carry about 11,000,000 cubic feet per day when running full. This canal is 34 miles long and terminates at a point nine miles above Placerville. It lies above the line of the one which the company propose for the city demand, and it will be possible to supply the latter from the former, if it should ever become necessary.

The high level canal is objectionable as an independent supply line, as it must be very much exposed to snow in inclement winters.

The low level canal, proposed for city supply, leaves the river at an altitude of 2,600 feet. This altitude is, as has already been remarked, not subject to any considerable objection on account of snow. Being above all known mines, it is free from the objection of silt, which accompanies all mining operations in a greater or lesser degree.

THE MOKELUMNE RIVER AND BLUE LAKES.

The Mokelumne River heads, with the South Fork of the American, in the high Sierras. One of its sources is the system known as the Blue Lakfs.

The Lakes have been surveyed, and their outlines are preserved in maps prepared by the survey of 1874, under the direction of T. R. Scowden, C. E. This survey not only included the Lakes, but also the line of canal, which unites the point of diversion from the river, and the head of the pipe line, and the line from this point to the hills within the limits of the City of San Francisco.

The present Board of Commissioners, having at hand the results of these surveys, are spared the necessity of repeating them, and these results govern in all estimates of cost which relate to this line. All exact statements of area, distances and quantities, used in the following description, are therefore to be credited to the survey and report of Mr. Scowden.

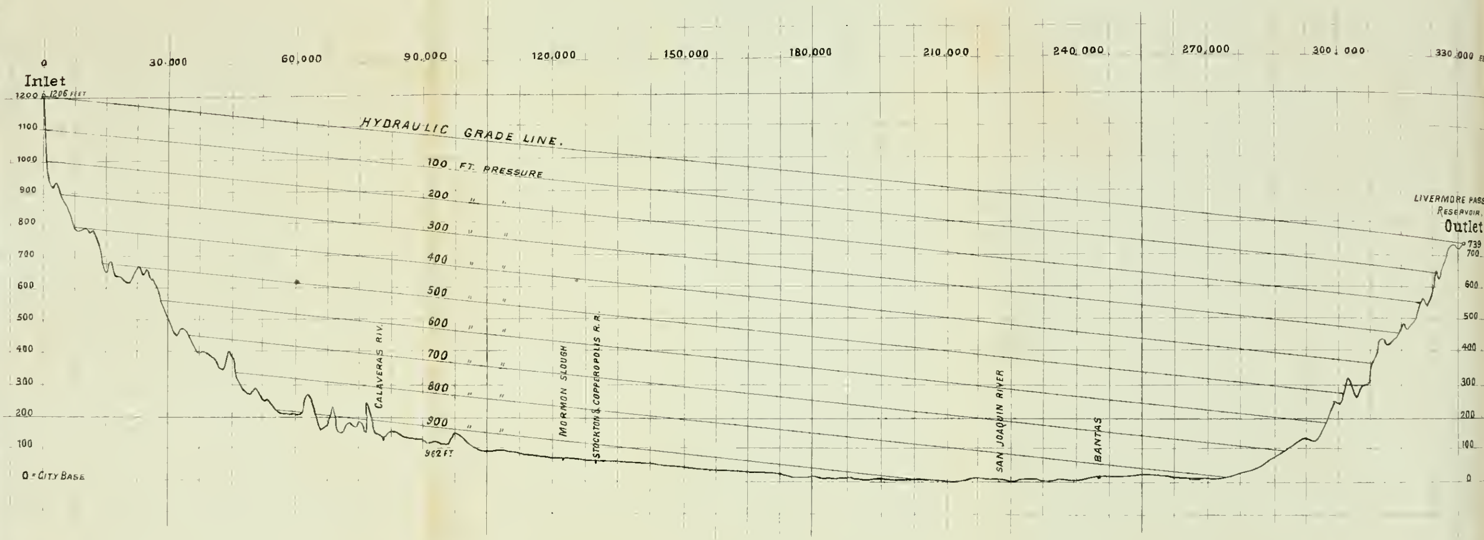
The Blue Lakes are three in number. The highest of the three has an altitude of 8,109 feet above the sea, and an area of 230 acres. The second in

BLUE LAKES LINE. PROFILE of Inverted Syphon from the foot hills of the Sierra Nevada to Livermore Pass Reservoir.

Total length of Pipe 330,748 feet Total fall to Reservoir 467 feet.

From Survey by T.R. Scowden, C.E. 1875.

Scale 1 inch to 30,000 feet.



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altitude lies, in distance, a mile and a half below the first, and in altitude 97 feet. Its area is 73 acres. Near the latter and above, lie the Twin Lakes, which are in reality a single lake, with an area of 30 acres. There is still another lake adjacent to the upper one, which has an area, not known to be surveyed but here estimated at ten acres.

The Lakes possess the characteristics of their fellows in the high altitudes of the Sierra. They are deep and are supplied by the melting snows, which ordinarily fall to great depth on the adjacent peaks and higher ridges. The quality of the water can hardly be questioned. The altitude is so great as to forbid all impurities resulting from human or artificial means. The temperature is so cool as to forbid the presence of much vegetable matter, if that be held as objectionable. The aerating process, which it undergoes in falling over the precipitous bed of the river, endows the water with the quality of agreeability to the taste, which at first, as liquefied snow, it failed to possess. The geological character of the country is granitic and its topographical features pronounced, with steep declivities, affording rapid drainage.

In all respects it has the advantages which belong to other regions of equal height visited by the Commissioners.

The value of these Lakes is to be found in their capacity for storage, which has been already established to be a necessary adjunct for the supply from rivers of the size and character of the Mokelumne.

It will be observed that in this respect the Lakes do not nearly equal the system, which has been described, as lying on the headwaters of the South Fork of the American. The storage capacity is, for stated heights of dam, as follows, viz.:

Upper Lake, with dam 42 feet high.....3,000 millions of gallons.
Lower Lake, with dam 49 feet high... .1,777 millions of gallons.
Twin Lakes, with dam 26 feet high..... 585 millions of gallons.

A total for these Lakes of 5,362 millions of gallons.

The total drainage area tributary to the Blue Lakes proper, which have been credited with 4,777 millions of gallons, is by actual survey 3,050 acres, and in order to collect this quantity it would be necessary to drain off from this drainage area 56 inches of water. A reference to our records at the Summit shows, for the year 1870–71, a fall of rain, or snow reduced to rain, of 37.77 inches. The whole of this fall, supposing it to reach the reservoirs without loss, would still fail to fill them to their full capacity, and would leave room for nearly 1,000 millions of gallons more. Further, if we apply the rule assumed in the treatment of the minima in the El Dorado reservoirs, namely, a drainage of 2¼ feet from the land, we obtain for years of minimum fall 2,212 millions of gallons, less than half the capacity of the two reservoirs.

The area of the Twin Lake basin is 884 acres. The minimum drainage from this will, by the same rule, be 650 millions of gallons. The reservoir

holds 585 millions; hence there will be an overflow into the other Lakes of 65 millions of gallons, raising their minimum to 2,277 millions.

About three miles from the lower of the Blue Lakes is a reservoir site, known as Deer Valley. This reservoir is proposed to hold, with a dam 102 feet high, 2,860 millions of gallons. The boundaries of the area tributary to this reservoir are sketched—not understood to be surveyed—on the maps of 1874. As thus sketched, the contents are 6,900 acres. Its minimum drainage will amount to 5,000 millions of gallons, considerably more than the capacity of the reservoir.

This reservoir site is quite unfavorable as compared with the Lakes, as will appear from the fact that it requires 471,300 cubic yards of embankment to impound 2.860 millions of gallons—whereas 248,800 cubic yards give sufficient capacity in the Blue Lakes proper to hold 4,777 millions of gallons.

It will appear from this statement that we may expect to impound by these reservoirs in the dryest season, no more than 5,722 millions of gallons, distributed as follows, namely:

Upper and Lower Blue Lakes.	2,277 millions of gallons.
Twin Lakes...........	585 millions of gallons.
Deer Valley reservoir........	2,860 millions of gallons.

This amount, being 57 millions of gallons for 100 days in the year, is an abundance for any present supply, but it will be apparent that, before the demand is increased to anything like the supposed ultimate degree, it will be necessary to provide very considerable additional storage.*

The resources of these reservoirs being regarded as inadequate for the future supply, and Deer Valley reservoir being an unfavorable site, the Commissioners directed a search to be made for other reservoir sites within the drainage ground.

As soon as the snow permitted the examination to be made, G. F. Allardt, C. E. was sent for the purpose. His examination resulted in finding a number of sites, which were instrumentally reconnoitered. They are as follows:

1. Upper Bear River, altitude 5,670 feet, in sections 4, 5, 9, Township 8 N., Range 16 E. Drainage area, 12 square miles. Minimum production, at 315 millions of gallons per square mile, 3,780 millions of gallons. A dam, maximum height of 70 feet, length on top 710 feet, length on bottom 30 feet, will impound 2,470 millions of gallons.

2. Lower Bear River, near the site just mentioned. Drainage area, 12 square miles. Minimum production, at 315 millions of gallons per square

* Partial returns of the rain and snow fall during the year 1876–77 indicate a probable rainfall at the summit not much, if at all, exceeding 25 inches, against 37¾ inches, the lowest previously known. Under this state of affairs it is plain that the minimum production of water, which has been assumed at 2¼ feet drained off the ground, ought to be reduced to 18 inches, or, what is equivalent, the minimum drainage from each square mile be taken at 315 millions of gallons. The product due to the Upper and Lower Blue Lakes may, under this hypothesis, be as little as 1,500 millions of gallons.

mile, 3,780 millions of gallons. A dam 70 feet in height, 1,670 feet long on top, and 35 feet long on bottom, will impound 3,940 millions of gallons.

3. Cold Creek, in Sections 13, 14, 23 and 24, Township 8 N., Range 16 E. Drainage area, twenty square miles. Altitude, 6,200 feet. Minimum production, 6,300 millions of gallons. A dam 70 feet high, 1,220 feet long on top, and 30 feet long on bottom, will impound 3,560 millions of gallons.

These sites are all on the streams which enter the Mokelumne from the north, above any proposed site for the canal head.

4. Lake Valley, two miles below the Twin Lakes, near the Blue Lakes. Altitude, 7,800 feet. Drainage area, 4½ square miles. Minimum production, 1,400 millions of gallons. A dam 70 feet high, 620 feet long on top, and 30 feet long on bottom, will impound 2,750 millions of gallons.

5. Bummer Flat, an insignificant reservoir.

6. Several other small reservoirs not surveyed.

The storage capacities for given depths of water at the dam are contained in the following table. Taking the dams at 70 feet in height, the total storage, in driest seasons, will exceed 10,000 millions of gallons, or 100 millions of gallons for 100 days.

TABLE, SHOWING CAPACITY OF ADDITIONAL RESERVOIRS EXAMINED IN JUNE, 1877.

(CAPACITY GIVEN IN MILLIONS OF GALLONS.)

Maximum Depth of Water at Dam.	60'	65	70'	75'	80'	85'	90'	95'
Bummer Flat........	750							
Upper Bear River	2,210	2,470	2,730	2,990	3,250	3,510	3,770	4,030
Lower Bear River....	3,460	3,940	4,420	4,900	5,380	5,860	6,340	6,820
Cold Creek..........	3,120	3,560	4,020	4,490	4,970	5,460	5,960	6,470
Lake Valley	2,480	2,750	3,030	3,320	3,710	4,010	4,320	4,640
Totals..........	12,020	12,720	14,200	15,700	17,310	18,840	20,390	21,960

The corresponding heights of the Dams five feet more than maximum depth of water.

The question of the character of dams, which ought to be built for the permanent storage of water in these districts, so remote from population and the centre of administration, and inaccessible in the winter, has been alluded to but it deserves more extended notice.

It seems plain from the statement of the case that the dams ought to be of the most solid and permanent character, with all possible safeguards against accident from any cause.

These conditions would be best fulfilled by the construction of granite dams laid in cement. The granite for the purpose is, it is believed, in all cases convenient, the hills and bed rock being all of granite. Under existing circumstances, however, the cost of building dams of this character would be very great. The cost per cubic yard could hardly be less than $20, and probably would be $25.

A less satisfactory construction, which has, however, been in successful use in the mountains during the past fifteen or twenty years for storage for mining purposes, may perhaps be used with propriety, at least for temporary purposes, until circumstances permit a cheaper construction in masonry than is now possible. The alternative construction consists in making a dam of dry masonry, using about three times the quantity of stone which would be required in a properly proportioned profile of a masonry dam. The faces are laid up by hand, and the interior filled with stone thrown in without laying.

The general character of the construction, which is that elsewhere referred to as used at Fordyce reservoir, will be apparent from the accompanying section. The beds of the stones in the wall on the water side are sometimes placed perpendicularly to the slope, instead of being laid horizontally. The cost of such a construction will, in favorable cases, be hardly one-third or one-fourth that of masonry laid in cement.

The prevention of leakage is secured with more or less success in different cases by a lining of plank, laid on timber built in the inner slope of the dam, the fitting with the bed rock being carefully made. The joints may be caulked. In some cases the plank is seasoned before laying, and the swelling due to the water brings about close contact. Earth is sometimes thrown against the inner slope to secure tightness. Making a due allowance for leakage, this character of construction in these high and distant regions is preferable to earthen embankments, particularly if they have a height more than a few feet.

The cost of these dams is estimated to be from two to three dollars per yard, the lower price when the stone is not quarried and is found conveniently.

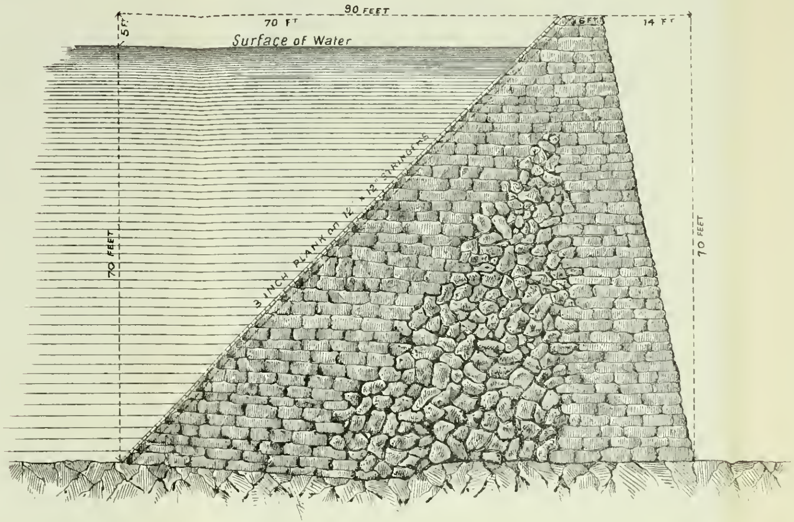
The following are approximate estimates of the cost of dams of this construction:

Upper Bear River	$100,000.
Lower Bear River	200,000.
Cold Creek	200,000.
Lake Valley	85,000.

The main features of the different reservoirs that have been examined in this drainage basin can be best stated in the accompanying table:

SKETCH of dry stone dam used for storage for Mining purposes in California.

Scale 1 inch to 20 feet



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MOKELUMNE OR BLUE LAKES LINE.

MOUNTAIN RESERVOIRS.

RESERVOIRS.				DAMS.				STORAGE CAPACITY OF RESERVOIR IN MILLION GALLONS.
NAMES.	Area of catchment basin in sq. miles.	Area of Reservoir in acres	Minimum Drainage in Gallons.	Maximum Height in feet.	Length on top in feet.	CONTENTS IN CUBIC YDS. Dry Masonry, Mining Type.	CONTENTS IN CUBIC YDS. Cement Masonry, Krantz's Type.	
Upper Blue Lake...	3	230	945,000,000	42	900	25,928	8,181	3,000
Lower Blue Lake...	2	73	630,000,000	49	1003	30,093	8,556	1,777
Twin Lake	1½	30	472,500,000	Lower = 26 Upper = 9	Lower = 1488 Upper = 416	Lower = 16149 Upper = 1576	Lower = 4869 Upper = 946	585
Lake Valley	4½	168	1,417,500,000	70	620	34,000	10,190	2,750
Upper Bear River ..	12	159	3,780,000,000	70	710	42,400	12,600	2,470
Lower Bear River ..	13	295	4,095,000,000	70	1670	81,500	24,800	3,940
Cold Creek	20	275	6,300,000,000	70	1220	85,000	25,320	3,560
Bummer Flat.......	5	69	1,575,000,000	65	780	65,800	20,100	750

It may be recalled that the Mokelumne, at the head of the Amador Canal, in September, 1874, ran as low as 14 millions of gallons per day. This is the lowest stage known to have ever been reached. If we suppose this low stage to have lasted one hundred days, which keeps us on the side of safety, then there would have been for this interval, under a daily draft of 25 millions of gallons, a deficiency of 1,100 millions of gallons, to which we may add, for loss by absorption and evaporation, 50 per cent., making a total deficit of 1,700 millions of gallons. About two thousand millions of gallons is the probable minimum amount of storage, which ought to be supplied, *pari passu* with the construction of a conduit of 25 millions capacity. The two Blue Lakes and Twin Lake reservoirs will be able to supply this amount. Further storage may be deferred until another conduit is projected.

In the survey of 1874, a line of canal was surveyed to take the water from the Mokelumne River and deliver it to a reservoir at or near the head of the pipe line.

The head of the canal was established at the altitude of 2,880 feet, at the mouth of Blue Creek. Its length was 51¾ miles. The head of the pipe line has an altitude of 1,206 feet, making a total fall in the canal of more than 1,600 feet. About 340 feet were consumed in the canal bed, which had a slope of 6.4 feet per mile. Adding to this all necessary allowances for falls in syphons, there was still a very large excess in height, which was overcome in successive drops. This excess of fall suggested the possibility of a lower site for the headworks, and a shorter canal.

There was an additional reason for looking for another route, in the fact that for the first eight or ten miles of the original line, the slopes of the mountains, along which the canal must run, were in places as much as 45°, and in some cases more. The construction and maintenance of a canal under such circumstances would alike be difficult, if not impracticable. The lower the canal is in altitude, the better it is on account of snow.

There are two alternatives. One is to take out a canal on the south bank of the river, at any convenient point near the head-works of the Amador Canal, 10 or 12 miles below the mouth of Blue Creek, and follow along the south bank until the large branch of the river, coming from the south, is encountered; cross this stream by an iron syphon and rejoin the line of the original survey at any suitable point below.

The second alternative is to divert the Amador Canal at a distance of 17 or 18 miles below its head, carry it across the Mokelumne by a syphon and intersect the line of the original survey some distance above Mokelumne Hill.

Either of these alternatives, if practicable, promised to save about 14 miles in length of canal, place it on better ground and in a safer position.

The saving in the cost of 14 miles of canal will be something like $350,000, or perhaps $400,000. The saving in supervision and repairs will never end.

These considerations were deemed of sufficient importance to require an examination of these alternative routes, in order to see whether there is any

reason in the topography or character of the country which forbids the execution of either of them.

Accordingly Mr. Allardt made, under the instructions of the Commissioners, an examination of the country, with pocket level and barometer, which proves that there is no topographical reason why either of these plans may not be carried out.

The facts appear to be the following: that the headworks of the Amador Canal are situated on the Mokelumne River in a favorable position, at an altitude of 2,200 feet, as established by an aneroid barometer. The river at this point has a rapid fall, which helps to dispense with the necessity of a dam. The headworks are in a position where the current of the river does not impinge upon them. The canal has a fall of ten feet per mile for the first two miles and afterwards eight feet per mile. Following the canal down 17½ miles, we come to the point where the canal can be carried across the river by a syphon 5,280 feet in length, supported as it passes the river by a bridge 200 feet in length. The maximum pressure on the syphon will be 1,095 feet. Reaching the south bank of the Mokelumne, the canal passes, through a depression, from the Mokelumne to the Calaveras drainage basin. Running through a natural channel, a fork of Rich Gulch, the line joins the original survey at Station 1774, altitude 1,665 feet.

For a canal on the south side of the Mokelumne, Mr. Allardt is of the opinion that the water can be taken out opposite the Amador headworks, although the position is not so favorable as the other side, from the fact that it is exposed to the current of the river. A tunnel, 1,000 or 1,200 feet in length, would carry the water out in such a way as not to be exposed to dangers from floods. Or, using the Amador headworks, the canal could cross the river about 1,500 feet below and follow the south bank. The route by the south bank will, it is thought, be shorter than the one by the Amador Canal by about one mile, and part of it will be on better ground. This canal would cross the South Fork by a syphon 5,100 feet in length, having a maximum pressure of 1,015 feet. The line will join the original surveyed canal at Station 1774.

The results of this examination must be regarded as quite favorable.

As between the alternatives of using the Amador Canal and building a new canal on the south bank, the latter is to be preferred. The Amador Canal can, however, fulfill all present demands. A careful examination of its condition has not been made. It is, however, known that its present capacity is much below the standard of 100,000,000 gallons per day. We may feel reasonably assured that the canal part of the conduit from the Mokelumne to San Francisco will not exceed 38 miles in length.

It is probable that with either of these shorter lines the Rich Gulch reservoir, which was contemplated in the original survey, must be abandoned on account of its altitude. It must remain for future examination to determine whether there will be any necessity to replace it. The greater safety of the new line will go towards justifying its abandonment.

THE RUBICON.

This is the middle fork of the American River. Its sources lie in the highest regions of the Sierra, west of Lake Tahoe. It drains a large area, sufficient for the water supply of the City. The area, character of the country drained, and the rainfall may be assumed as equal to those of the South Fork or the Mokelumne. In the early part of August large fields of snow remained unmelted on the higher ranges, and at this time the river carried 300 millions of gallons daily at the point visited by the Commissioners, nearly opposite Michigan Bluffs.

In this part of its course the river resembles the other mountain streams which have been described, except perhaps that it has eroded a deeper bed. It has a rapid descent over a narrow, rocky channel, which is enclosed between walls, almost precipices on either side, 2,000 feet in height.

It possesses, as do the others, in the higher levels of its drainage basin lakes suitable for storage, which would be essential to be provided, in case the river should ever be used as a source of supply.

The lakes and upper regions of this drainage basin are difficult of access, none of the main traveled routes across the mountains passing through this region. The examination of the Commissioners was confined to the river itself.

This belongs to the northerly group of supply sources, and the conduit route would naturally correspond to the line surveyed from Auburn, in that it would follow the Sacramento Valley, and reach Oakland by way of Carquinez Straits. We have no survey of that part of the route which lies east of the Sacramento River.

THE SOUTH YUBA.

This is one of the main branches of the Yuba. It heads with the North Fork of the American. It has a number of reservoirs, impounding a large quantity of water, which is carried by a canal, one branch of which goes to Dutch Flat and another to Nevada City. The principal reservoirs are Fordyce Valley and Meadow Lake.

The former is closed at its outlet by a dam, not completed at the time of the visit of the Commissioners. It is now 75 feet in height at the highest point, and it is expected that it will be raised about 30 feet more. The dam is made of dry stone masonry, laid up with care, with a batter of one in base to four in altitude on the outer side. The inner slope is 45°. This slope is lined with three-inch plank, against which earth is filled. The dam has a base, at its widest part, of 165 feet. The area of the reservoir is supposed to be in the neighborhood of 1,200 acres. In the past season it contained a depth of 43 feet of water at the dam.

We did not see Meadow Lake. It is described as containing 600 acres, and is dammed to the height of 40 feet. There are a number of other lakes, known as White Rock and Lost River Lake, of about 100 acres each; and still others of smaller area, several of which have been converted into reser-

voirs. These lakes and reservoirs will, in the aggregate have a much larger capacity than the city would ever require.

The canal is taken from the South Yuba, at an altitude of nearly 5,000 feet, as noted by the barometer. It is therefore very much exposed to heavy snows, which were represented to attain a depth of fifteen feet at the head-works. This fact would be a serious objection to the use of this canal as a link in the conduit for city supply. This altitude is very much in excess of any proposed canal line appertaining to other rivers.

It may further be remarked that all the water which this Company has succeeded in storing is used and required for mines at Blue Tent, Dutch Flat and Nevada.

The route to San Francisco would be by canal to the reservoir near Auburn, and thence by a closed conduit to the city.

This property has passed into new hands within the last year, and it is understood that it is not now offered to the city.

This review completes the description of the sources of supply in the Sierra examined by the Commissioners. It does not, however, exhaust the list. There still remain: The STANISLAUS RIVER, lying to the south of the Mokelumne; the NORTH FORK OF THE AMERICAN; the FEATHER RIVER, lying still north of the Yuba; and the SAN JOAQUIN. The sources of all these rivers are in the Sierra Nevada.

SURVEYS.

Having completed these examinations, the Commissioners decided to ascertain, as nearly as possible by preliminary surveys, the comparative cost of the introduction of water from the different sources.

There are two independent routes by which it has been proposed by their promoters to carry the conduits:

For the more southerly sources of supply, namely, the Blue Lakes and El Dorado, the route by Livermore Pass is the more direct.

The route, advocated for the northerly sources, has always been by way of the Sacramento Valley across the Straits of Carquinez; thence to Oakland, which is five miles from the city, the Bay of San Francisco intervening.

The survey of 1874 had run a line from the Mokelumne River and Blue Lakes to San Francisco, by way of Livermore Pass and Ravenswood. The Clear Lake line, also surveyed in 1874, crossed the Carquinez Straits and proceeded to Oakland.

The surveys of parts of the Sierra lines were thus at the service of the Commissioners. The parts which had not been surveyed were:

For the northern route, a line from the reservoir near Auburn to a point near Fairfield, where it joined the old Clear Lake survey. This line is common to the Tahoe, North Fork of the American and South Yuba projects.

On the other route, the part not surveyed was, for the El Dorado project, a

line from Johnson's Ferry on the San Joaquin, where the Blue Lake line crossed, to a reservoir to be found near Latrobe.

Reservoir sites were found and surveyed, two near Latrobe, and two near Auburn; their capacities were determined, and the quantity of material for the dams ascertained.

These surveys were preliminary. They consisted of a transit line, and levels affording a profile of the country passed over. Being preliminary, they could only by accident coincide with a locating survey. They were not intended as a survey for actual construction. It is thought proper to draw attention to this fact. Perhaps no railroad was ever built upon a preliminary survey, and the conduits which we are considering are more expensive per mile than most railroads.

These surveys were commenced in September and occupied two months and a half. Since the return of the parties to the city, the time has been taken up in making the map and profiles of the route, and in calculating the items of about twenty different lines; the last being by far the most laborious part of the work.

It is thought proper to remark that, although these surveyed lines could only by accident be the routes on which construction would be made, the estimates of distance are made as nearly as possible on the shortest lines. This is quite practicable in the valleys, since the slopes and topographical features do not differ greatly on lines, having the same general direction and not far separated by distance.

THE MANNER OF BRINGING WATER FROM THE SIERRA NEVADA TO THE CITY.

Mention has already been made of canals. They form the eastern link or part of the conduits in all cases.

The heads of the canals ought to be established on the rivers, above any considerable mining operations, present or prospective. These operations are common to all the rivers, but they do not, as a rule, exist above an altitude on the rivers exceeding 2,500 or 3,000 feet. Here, at or about the eastern limit of the mines, is a suitable general position for the head of the canal, which is to deliver water at the point where the iron conduit begins. This upper part of the conduit is not, however, all canal. Where its line intersects ravines, it becomes necessary to carry up an aqueduct to the grade line of the canal, or otherwise to pass the water by means of an inverted syphon, the latter being the plan usually adopted.

At the lower extremity of the canal a reservoir is provided, at an elevation sufficient to give the necessary fall to the pipe, so as to insure the delivery of the water at the required height in San Francisco.

Looking to the future, when an increased supply, amounting to 100,000,000 gallons per day will be required, it is deemed advisable to give these canals capacity sufficient to carry the ultimate demand, so that no enlargement of them will be required. This is an important feature, for the reason that

no enlargement of a canal could take place without a long interruption of its flow.

It will be remembered that the rivers are 2,000 feet, more or less, below the ridges which inclose them on either side. The canal is then, in the first miles of its alignment, compelled to follow the flanks of these high and steep ridges. If the river falls 100 feet to the mile—and this fall is not infrequent—and the canal falls eight feet per mile, then it will appear that a point on the canal one mile below the head will be 92 feet above its corresponding point in the river. Otherwise expressed, the canal gains on the river an altitude of 92 feet for each mile. In twenty miles the canal gains 1,840 feet, and if this be the altitude of the ridge above the river, at the end of the twenty miles the canal will emerge from its alignment on the flanks, to occupy a position on the flatter land of the top. In a certain sense, the canal may be said to have climbed the ridge.

The transverse slopes of the ridges are generally quite steep; in some cases, they are as much as 45°. Here and there, where a projection of rock occurs, the slope may be even vertical. At such places it is sometimes impracticable to build a canal, unless by tunneling. A flume or box of wood, placed outside of the slope, is made in some cases to take its place. Wood will last about 15 years. At the end of this time it would be necessary to rebuild the flume.

The canal and its accessories may be briefly described as follow, namely:

At the head of the canal, it will generally be necessary to build a dam across the river, to raise the water to the level desired in the canal. This dam ought to be built of masonry, in a secure manner, because it will, year by year, be exposed to heavy floods. There are exceptional points, where a natural barrier exists in the stream, and where no artificial dam is required.

The headworks of the canal ought also to be in masonry. The portion of the canal adjoining the headworks will generally be exposed to floods, and when this is the case substantial masonry protection will be required.

Knowing by survey the fall of the canal, its dimensions can be proportioned to the quantity of water to be carried.

But one of the canals proposed has been surveyed, and that is one on the Blue Lakes line, surveyed by T. R. Scowden, C. E.

The canal is to be lined with stone, without mortar, one foot in thickness, both on bottom and on the sides, in all places where excavation is in earth. Where the excavation is in rock, or in a material which will not yield, the lining can be omitted.

The channel of the canal on the side hills will be wholly in excavation. The inner slopes are four vertical to three base, to be modified on steep hill sides, where this inclination is impracticable; or in rock excavation, where banks are stable at any inclination.

Without encumbering this report with details, it may be stated that every precaution which many years of Californian experience has proved to be necessary—in preparing the ground; in construction of banks and wastewiers;

in crossing streams, and in other important features—are contemplated for this work. In addition, all practicable arrangements for protecting the canal from injury, and for keeping the water clear, are proposed.

The dangers to which works of this kind on mountain sides are exposed are: falling of trees, avalanches of snow, or slides of earth or rock.

The first can be met by previously removing all trees likely to do any injury.

Snow or earth slides must be met when they occur. The earth slides, at the altitude above the sea proper for a canal, are the most formidable obstructions. By filling and obstructing the canal, they cause the banks to be overflowed and washed out. This difficulty is met by constant supervision. In canals used for mining purposes, it is usual to keep a man to patrol each division of ten miles every day.

The water in the rivers, as the Commissioners saw it, was always clear. There are times, however, when the rivers carry a greater or less amount of silt. The banks and bottom of the canal being paved they are protected from erosion; therefore the silt which the canal carries will be taken in at its head, or will come from slides of earth along the line. Provision ought to be made by settling reservoirs, that the silt may not be carried into the pipe lines. In this point of view, one or more reservoirs along the canal line are desirable. One reservoir at the head of the pipe line is indispensable. Without such a reservoir, a breach in the canal would interrupt the supply delivered in the city, which could be resumed only when the breach was repaired. A few days' supply in a reservoir at the head of the pipe line would permit the delivery in San Francisco to go on without interruption.

THE IRON CONDUIT

FROM THE FOOT-HILLS OF THE SIERRA NEVADA TO SAN FRANCISCO.

This conduit necessarily consists of one or more inverted syphons. The topography of the country forbids the application of masonry conduits, such as are used in gravitation lines supplying other cities either in America or Europe. Masonry conduits require a fall from their heads to their points of delivery, which shall be uniform per mile or vary within narrow limits. The conduit of masonry must fall continuously. It cannot descend to rise again without bringing into action a pressure which it is never intended to resist.

All of the lines from Sierra Nevada to San Francisco descend first into valleys—either the San Joaquin or the Sacramento—and after passing them they rise over hills of considerable elevation, again to descend before reaching the city.

These circumstances compel the use of iron or steel. The pressures along the line and the circumstances of transportation are such as to forbid the general use of cast iron, and the choice becomes restricted to wrought iron or steel.

The application of wrought iron pipe for the conveyance of water is quite familiar to Californians; probably much more so than to the people of any other part of the world. The necessities of mining operations originally gave birth to the system, and it has since been developed with a boldness that astonishes the professional engineer, who is familiar only with the processes and rules of more conservative communities. The experience of California must be held to govern in the treatment of the strength, strain and thickness of pipes, subject only to such conditions as a reasonable prudence may suggest; which takes into consideration the special requirements of the end proposed, and leaves sufficient margin of safety for accidental or unforeseen circumstances. The experience of California has been wider and more comprehensive in this particular regard than that of any other community. It is therefore to this experience that we must turn for instruction.

The main expense of each of the schemes under consideration will be found in the construction of the pipe line.

It may be expected that there will be a variety of opinions upon questions relating to the strains and thickness of iron; and this among persons who have reasons for their opinions. These points will doubtless be the subjects of discussion.

These considerations seem to require a notice of this part of the work, more in detail than perhaps would, under different circumstances, be proper in a report of a general character.

It is assumed for the present that wrought iron pipes, presenting a smooth and unbroken internal surface, cannot be obtained. There are manifest advantages belonging to this kind of pipe. It is not, however, manufactured in sufficient sizes outside of England. We therefore consider the riveted pipe and the description known as double riveted. By this is understood a pipe with the longitudinal seam made by two lines of rivets. The round seam, by which the successive lengths are united, is exposed to less strain than the longitudinal seam and has but one line of rivets.

Wrought iron is assumed to have a tensile strength of 50,000 pounds, which means that a bar of square section, one inch on each side, or any other section having an equal area, namely, one square inch, would be ruptured by a strain of this amount, applied to extend the bar. This strength is assumed for discussion and for determining thickness. Iron of less strength may, it is thought, be used with advantage, the thickness being adjusted to the proper standard. The double riveted joint falls short of the strength of the iron, the loss being 30 per cent. The strength of the longitudinal joint is therefore 35,000 pounds per sectional inch of metal.

The important question is, what proportion of 35,000 pounds can be safely borne or, otherwise expressed, what factor of safety is essential? Shall this factor be two, three, four or more, or less?

The practice or rule of safety in California has varied very much. A published report of H. Schussler, the Chief Engineer of the Spring Valley Water Company, notices a pipe used in the mines where the iron is strained to 20,000

pounds, which, taking into account the character of the seam, is stated to be within 20 per cent. of the rupturing strain. It is not known for what length of time the strain was on the pipe.

The practice in the Spring Valley Water Company is stated, in the report alluded to, to vary in their latest pipes from 11,400 to 13,100 pounds, these being the strains on the San Andreas pipe.

Reference to the profile of the Virginia and Gold Hill water pipe, hereto attached, shows that the iron is under a maximum pressure of 1,720 feet. (The description of the pipe is taken from the *Mining and Scientific Press*, edition of December 13, 1873. It is believed to be authentic.) The pipe did not have taper joints, but the alternate sections have different diameters, the difference being twice the thickness of the iron. The No. 9 iron is strained fully 15,000 pounds to the sectional inch; No. 7 is strained above 14,000 pounds. The material used in this pipe was inferior English iron, of less strength than the quality of American iron which is assumed in our own calculations. This pipe has been in use five years, and is believed to be in good condition. It is seven miles long.

The profile of the Cherokee pipe is also represented by diagram. It is not subject to as high pressure as the Virginia pipe. It is however larger, and has been in use seven years, and is now represented to be in good condition. The strains on this pipe are stated on the face of the diagram. They run as high as 17,500 pounds, and every separate thickness above No. 14 has a strain exceeding 15,000 pounds. The iron used in this pipe was not selected, but was the average as found in the market.

No tests of the strength of the iron are known to have been made in any of these cases.

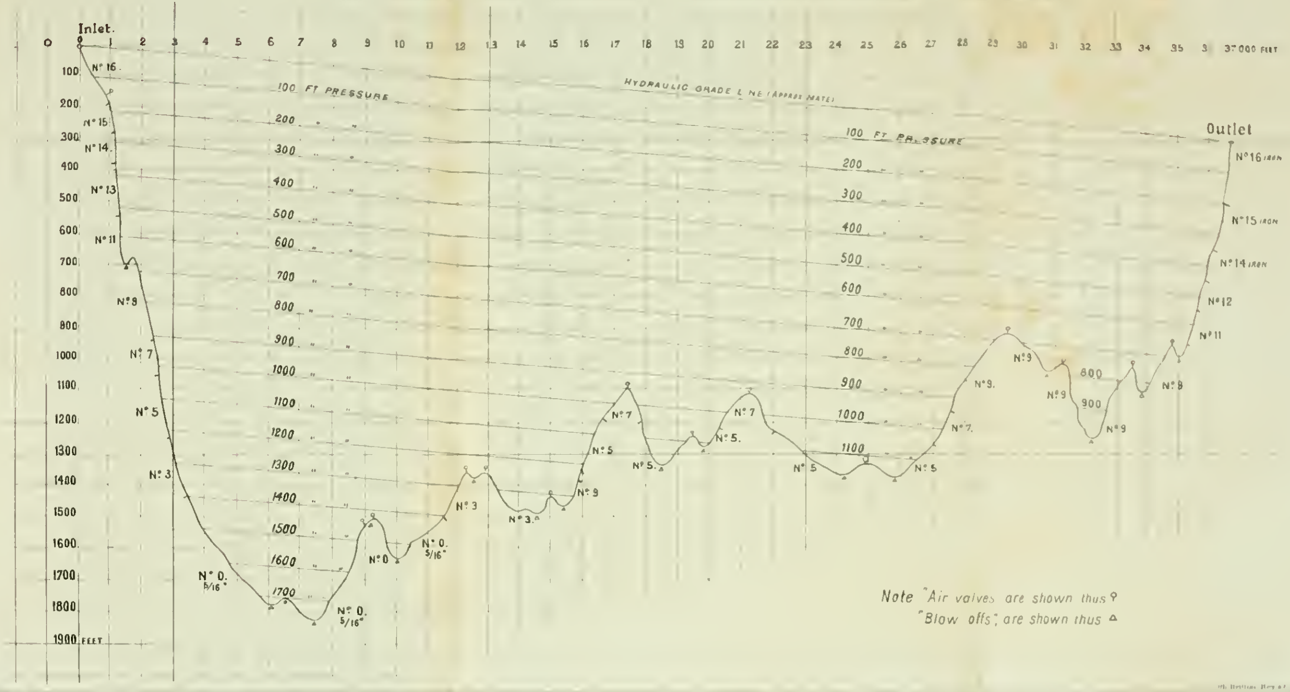
It is admitted that a city conduit ought, in common prudence, to have a larger factor of safety than a pipe used in mining operations, where a breach entails consequences of little importance. On the other hand, serious inconveniences would follow frequent breaches in a city conduit. If they should be sufficient in number, they might even prove disastrous. These breaches are, however, most to be expected when the water is first let into the pipe. If the pipe is not laid with precaution, settlement may produce undue strains and prepare the way for rupture. When the water is running through the pipe, the strain is steady and quite free from shocks.

We find in our examples an inferior iron strained to as much as 15,000 lbs., supporting it for five years. We also have an instance of average iron of good quality—but not so good as we assume for our proposed constructions—bearing for seven years a strain of 17,500 lbs., which is quite half the probable rupturing strength of the iron.

In the judgment of the undersigned, this experience justifies the conclusion that it is both reasonable and prudent to put a strain of 14,000 lbs. on the iron, proposed for the city water supply. The rupturing strain on the seam being 35,000 lbs., the factor of safety is two and a half. There are many persons having experience in constructions of this kind who will think that this

Profile of Iron Pipe for the Virginia & Gold Hill Water Works.

Average diameter of Pipe 11 inches. Circular seams single rivited, longitudinal seams double rivited. Capacity about 2,000,000 gallons in 24 hours. Pressure 1720 feet or 746 pounds per square inch. Length of pipe about 37,100 feet. The numbers along the line of the pipe show the thickness of the iron by the Birmingham gauge. Laid in 1872 by Hermann Schussler C.E. Engr. Total fall [illegible]



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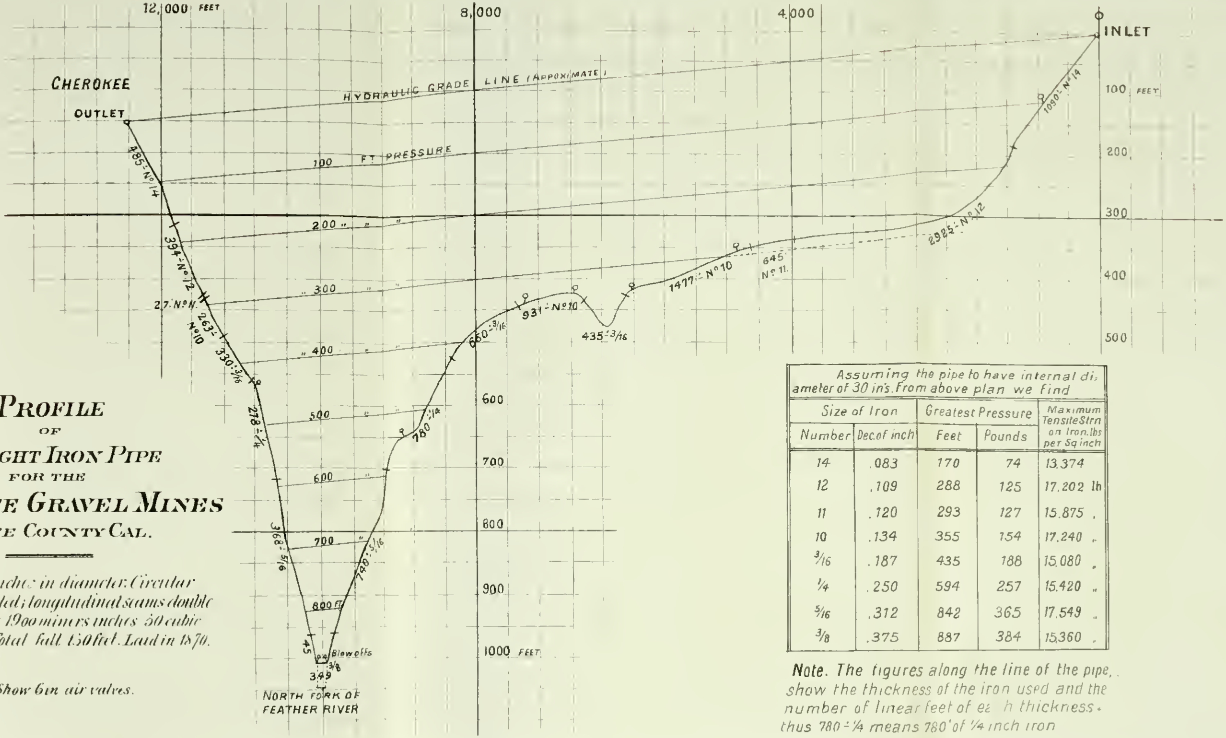

PROFILE
OF
WROUGHT IRON PIPE
FOR THE
CHEROKEE GRAVEL MINES
BUTTE COUNTY CAL.

Pipe 30 inches in diameter. Circular seams single riveted; longitudinal seams double riveted. Capacity 1900 miners inches 50 cubic feet per second. Total fall 150 feet. Laid in 1870.

♀ Show 6in air valves.

Assuming the pipe to have internal diameter of 30 in's. From above plan we find

Size of Iron		Greatest Pressure		Maximum Tensile Strn on Iron. lbs per Sq inch
Number	Dec. of inch	Feet	Pounds	
14	.083	170	74	13.374
12	.109	288	125	17.202 lb
11	.120	293	127	15.875 "
10	.134	355	154	17.240 "
3/16	.187	435	188	15.080 "
1/4	.250	594	257	15.420 "
5/16	.312	842	365	17.549 "
3/8	.375	887	384	15.360 "

Note. The figures along the line of the pipe, show the thickness of the iron used and the number of linear feet of each thickness. thus 780' 1/4 means 780' of 1/4 inch iron

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factor is too high, and that it might be reduced with propriety to two. It is preferred however in a matter of this importance, to keep well inside of the limits afforded by our experience, which extends only over a few years.

The life of the pipe will depend mainly upon the security given by the bituminous coating, which must be applied both externally and internally. When this fails, rust and solvent action of the water will set in, and begin to affect the pipe injuriously.

The Spring Valley pipes have been in use about thirteen years, and they are represented to be in good condition. This is the longest experience of a long line of pipe which we have in California in this particular regard.

It has been remarked that iron of inferior strength may be used, regard being had to its thickness, which is to be adjusted to the diminished strength. The hard irons of low tensile strength are less subject to rust, and in this respect it may be a positive advantage to use them.

A pipe of low steel, or, as it is sometimes called, Ingot iron, welded so as to give a smooth internal surface, would possess several advantages. Its tensile strength being higher than iron, equal diameters would require less metal. This advantage in weight would be increased by the fact that the welded joint may be made, at least for iron pipes, 15 per cent. or more stronger than the double riveted joint. Being smooth, the pipe would carry considerably more water. The manufacture of this material has been much cheapened in the last few years. Inquiry has been made, both as to the practicability of obtaining this material at a suitable price, and further, as to the process and expense of making welded pipes, but at this date our information is not sufficient for further remark.

The usual arrangements for admitting or expelling air from the pipes—small exit valves at the low points, and man holes about 1,000 feet apart—are contemplated and are included in the estimate.

The sizes of pipes in different lines vary. The diameters are proportioned to carry the same quantity of water which is that for a riveted pipe, smallest interior diameter being 40 inches, with a fall of 7.43 feet per mile, namely, twenty (20) millions of gallons per day.

A similar pipe, 48 inches interior diameter, with the same fall, will carry thirty-two (32) millions of gallons.

The condition of hydraulic science is such that it is quite impossible to state the delivery of riveted, or even of smooth pipes of untried fall per mile and dimensions, with positive accuracy. Without going into a discussion of formulæ, and of their agreement or disagreement with observed results, which would materially increase the length of this report, it may be remarked that the assumed capacities have been calculated by Darcy's formula.

Instead, however, of taking the full diameters, deductions of 1½ inches have been made in each case—that is, the capacity of a 38½ in. smooth pipe is calculated for 40 in. riveted pipe, and 46½ in. smooth for 48 in. riveted.

The pipe will be laid in a trench, and will have a minimum covering of 2½ feet of earth.

It will cross rivers and smaller streams on wooden bridges supported by masonry abutments. Where the rivers are navigable, as are the Sacramento and San Joaquin, the pipe will underlie the bottom by tunnel or otherwise, as may prove most advisable.

The crossing of the overflowed land bordering the rivers will require particular study and attention. Allowance is made in the estimate for bridging the whole distance. It is not, however, anticipated that this will be necessary. On parts of this ground it may be necessary, to provide unrigid joints to make allowance for settlement.

The road crossings will require special arrangements for protecting the pipe from the wheels of heavily loaded wagons.

These points and other details must await for solution the final location of the line.

The estimates for the pipe are based upon a lap, both for the double and single riveted joint.

It is known that a butt-joint with straps gives more strength. It also requires more iron and more rivets. At about $\frac{3}{8}$ in. thickness it will probably be advisable to make the joints by straps. It is assumed that whatever additional iron and labor may be required to make the strap joint will be compensated by its increased strength.

It is almost indispensable for intelligent procedure, in a work of this magnitude, to investigate the subject of the best form of joint for the particular purpose of carrying water.

All experiments on these joints heretofore made have had for their object, either to obtain the best form of rib or the best joints for steam, neither of which correspond in all respects to the carriage of water.

It will be proper, therefore, before constructing a line of this magnitude, to ascertain by experiment the joint which, for a given expenditure, will afford the most strength and at the same time carry water without leakage.

Gates are provided at the head of the syphons, but no stops are placed in the pipes. For instance, on the lines by way of Livermore Pass, a gate is provided at the reservoir, at the head of the pipe line. There is no gate between this point and Livermore Pass reservoir, a distance of 63 miles on one line and 82 on the other. If the latter reservoir receives more water than it requires, the keeper at the upper end of the pipe is notified of the fact by telegraph, and he regulates the discharge as may be necessary. Between Livermore Pass and San Francisco the discharge must be regulated by the keeper at Livermore Pass.

If a breach occurs in a low part of the syphon, all or nearly all the water in the pipe will of course escape. It would certainly be convenient to have a series of stop-gates in the pipe to save this loss. Such an arrangement would, however, change the whole character of the problem. With gates only at the head of the pipe, the flow of the water is steady, and the pipe is free from shocks. The pressures on the pipe are hydraulic, as distinguished from hydrostatic.

For instance, let a gate be placed in the low part of the syphon in the San Joaquin Valley, where the pipe is at a height say six feet above the city base. When this gate is closed the pressure on the gate and pipe becomes hydrostatic, or instead of being as now, 950 feet, it rises to 1,200 feet, bringing an increase of 108 pounds to the square inch. This increased pressure would require a thicker and stronger pipe.

Above this gate there may be 30 miles of pipe, suppose it to be four feet in diameter. In this 30 miles there will be at the moment the gate takes up its motion 62,175 tons of water, moving at a velocity a little more than four feet a second or more than 2⅔ miles an hour. The motion of this mass is to be destroyed.

To place the character of this action in a familiar light, it may be stated that the destruction of living force is equivalent to that involved in stopping a cannon ball weighing 2,000 pounds, having a velocity of 1,000 feet a second. A sudden closing of the gate would produce an effect equivalent to that of the cannon ball, and no strength could be given to a conduit which would enable such a shock to be borne safely.

A regulated motion, occupying considerable time, combined with relieving valves to permit the escape of water, whenever the pressure exceeds a fixed limit, would do much to relieve the shock. A system of gates spaced along the line several miles apart, with a manageable quantity of water included between them, worked simultaneously, would however be the only safe plan, giving thorough control of the water column.

A careful study has been made of the action of stop gates on these lines. The means and appliances, necessary to regulate the shocks within safe limits, have been worked out in principle and partially in details. Each gate ought to be made in three parts, each of which can be opened or shut independently of the others.

It is proved that the gate may be moved with comparative rapidity in the earlier part of the closing process, and that the amount of the shock can be kept within safe limits during this interval. The last part of the motion must, however, be regulated with the utmost nicety, and with decreasing velocity. Any want of care in this phase of closing instantly raises the pressure excessively.

It is not thought necessary, at this time, to go into the discussion which proves these conclusions.

Under these conditions, a system of gates distant from each other, to be worked simultaneously and with great nicety, would in all probability prove too delicate and therefore unsuitable in practice. It would certainly add considerably, both to the original cost of the work and to the cost of maintenance.

It is therefore thought that it will be better to bear the loss of water and whatever other inconveniences may follow breaches in the pipe—which there is no reason to apprehend will be frequent—than to resort to the expense necessary to avoid or control them.

A telegraph line is at once seen to be an indispensable feature of the system.

The subject of change of length of the pipe, under varying temperature, deserves remark.

The temperature of the water which enters the pipe may be taken to vary, at different seasons, between 45° and 60° Fahrenheit.

Wrought iron expands or contracts for each degree of varied temperature .0002507 inches for each yard in length. An increase of twenty degrees in temperature would lengthen a bar one yard long by five thousandths of an inch.

If we suppose the iron to take the temperature of the water, it will mark at one season 45° and at another 60°, and the question arises whether any device of compensation joints ought to be adopted, to meet the tendency to stretch at one time and to contract at another. There are a number of forms for these joints.

If the pipe were exposed to the sun and air, under the great changes of temperature which occur in our climate, especially in the interior valleys where the range is not far from 100°, it would undoubtedly be necessary to provide such joints; otherwise there would be a bodily motion of the pipe.

With a pipe laid in a trench, covered with earth, and subject only to the limited range of the varying temperature of the water, the case is quite different. In all the pipe so laid in the mining districts of California and Nevada, there are not, so far as is known, any compensation joints. The Virginia and Gold Hill Pipes—which are situated in the mountains above Lake Tahoe, nearly if not quite 8,000 feet above the sea, where the temperature of the water changes with larger variations of temperature than in our cases—have not been injured in the absence of these joints. These pipes are only 10 and 12 inches in diameter.

Whether it be that the iron maintains nearly the same temperature—being that of the ground which in our climate, at a depth equal to that of the trench, does not vary much if at all—or, whether the iron takes the changing temperature of the water, and that the strain thus developed is well within the elastic limit of the metal, in either case the fact seems to be established that the questions of expansion and contraction, which at first glance appear serious are not, under our supposed conditions of much practical importance.

For any portion of the pipe not buried in a trench, the relations are probably different.

THE RELATION OF THE BAY OF SAN FRANCISCO TO LINES FROM THE SIERRA.

San Francisco can be approached by land only from the south. The Bay of San Francisco bounds the city on the north and east, and extends about thirty miles southeast of the city. The detour, for the sake of keeping the pipe on

dry land, is for some Sierra projects so considerable that it would make the lines impracticable on account of their length. It thus becomes necessary to enter upon an inquiry as to the modes of crossing the Bay, regarding their practicability and safety.

We can conceive a tunnel from shore to shore in which a conduit might safely be placed, where it could be visited and repaired whenever occasion required.

We may suppose a pipe laid upon the bottom of the Bay or in a trench excavated in the mud and sand to a depth sufficient to insure against any risk of damage from anchors of vessels. This pipe could not be reached or replaced by any easy or convenient means.

A third proposition is to lay an iron tunnel in a trench on the bottom, in which the conduit lies subject to inspection and convenient for repair.

These three propositions are the subject of our inquiry.

The narrowest crossing is at the throat of the bay, BETWEEN FORT AND LIME POINTS. The width from shore to shore is a trifle in excess of one mile. The velocity of the current is excessive, particularly in the lower depths. This is known from observation, and it is probably due to this fact that a submarine valley has been worn in the rock to the depth of 400 feet. The shores are rock. On the Fort Point side it is a mottled greenish serpentine, treacherous and hard to work. Lime Point rises abruptly to a height of several hundred feet. Its structure varies. In the main it is in appearance a jaspery rock, quite common in the vicinity of San Francisco, where it is popularly styled "red rock." Professor Whitney classes it as an imperfect serpentine. It occurs in very thin layers, often not more than an inch or two in thickness, which are upturned at steep angles of declivity, and often contorted like the rumpled leaves of a book. In connection with this structure occur masses of an extremely refractory rock of greenish tint, the mineralogical character of which is in doubt. It would be hard to find a material more obstinate to drilling.

The pressure of the column of water known to exist is 180 pounds to the square inch. The soundings, which have been taken for purposes of navigation, afford all known information as to the bottom. It may be that there are still greater depths than are given on our charts. A very considerable allowance would be indispensable to make up for possible depths and fissures, and to guard against the consequences that might follow from a very small crevice under a pressure of 180 pounds or more to the square inch. Perhaps 100 feet would not be too much allowance. Making this allowance, the tunnel would be 500 feet below the sea level. The length of the tunnel would be perhaps one mile and a quarter, possibly a little less. One of the shafts at the extremity of the tunnel, and perhaps both, would have a depth of 500 feet, increased by the height of the ground above the sea which at Lime Point might be considerable.

These are the main features of the plan. In sound rock there would be no

special difficulty that could not be foreseen or allowed for. We cannot be certain what may be the condition of affairs at and below the bottom. If the convulsion—if it were a convulsion which opened the Golden Gate—stopped in its action at the depth of the bottom and left no fissures or uncertain spots below, the execution of the tunnel would entail no extraordinary difficulties, but in the broken structure which exists there is room, in the absence of positive knowledge, for uncertainty. If shafts were sunk to the level of the tunnel on either side there would probably be grounds for positive opinions, which can now be but speculations.

It may be remarked that a submerged pipe and a submerged tunnel would be equally impracticable at the Golden Gate.

A tunnel or a series of tunnels, exposed to less pressure from superincumbent water, but of greatly increased lengths, might pass from Point Cavallo, near Lime Point, to Black Point; or from Peninsular Point, crossing Raccoon Straits to Angel Island, thence to Alcatraz, and from Alcatraz to the northern shore of the City.

The first of these lines is three miles in length, with 30 fathoms of water near its further end, shoaling to six or seven fathoms. It is not known whether or not the rock is deeply overlaid with sand or gravel. This line would be worked from the ends. It is between two and three times the length of the Golden Gate channel. Both shores are rocky but full of seams, which are characteristic of the vicinity.

By way of Angel Island and Alcatraz the tunnel under water would be 3¾ miles with six working points. The deepest water in Raccoon Straits is 150 feet, and on the line 170 feet. The increased length of this line, as compared with the route from Cavallo to Black Point, would probably be more than compensated by the facility for work, given by six points instead of two. On Angel and Alcatraz Islands there would be quite a mile which might be all or part tunnel, but with no special difficulties.

Another route, still longer, is that from Oakland to San Francisco. Yerba Buena Island ought to be a working point on this line. The shortest line would be about 4¾ miles, leaving out nearly three-fourths of a mile of the line, which would be on or under the island. From Oakland Point to Yerba Buena is scant three miles. It might be advisable and practicable to carry out a structure in the Bay for a mile or a mile and a half, and at its extremity sink to the level of the tunnel. There would be four working points on the line, and the deepest water about 150 feet, but this only for a short distance.

We have some information in regard to the strata underlying the Alameda shore, derived from a well which was sunk on Oakland Point, about 700 feet, in search of water. At a depth of 80 feet the boring entered a stratum of clay 43 feet thick. Sand and pulverized talc were found mixed with clay. If this stratum proves suitable, and if it extends across the Eastern channel, there is a fair prospect as far as Yerba Buena Island. The portion of the

tunnel between the island and San Francisco will necessarily be lower on account of the depth of water than the level of the clay stratum. It is probable that its line will be in rock, of the character shown at Yerba Buena and on Telegraph Hill.

If this clay layer prove impracticable there is another fair prospect at about 200 feet in depth, where a stratum of blue clay was found, over 30 feet in depth with a layer of gravel in it. Passing this, there is not much promise of success until the hard rock is reached at a depth of 534 feet.

At Ravenswood, 25 miles southeast of the city, the Bay is a mile and a quarter in width, between low and marshy shores. Over three-fourths of this distance the water is less than 18 feet in depth, and in the remaining half mile the greatest depth is eight fathoms. Nothing is known of the underlying strata. The approaches to the crossing on either side are over marshy land.

This closes a brief enumeration of the known facts, which hardly justify an expression of opinion on the practicability of the work, and certainly leave room for doubt. Reasonable conclusions are of course possible, but possible only with a good deal more knowledge than we possess. The requisite knowledge can be obtained by a sufficient number of borings to ascertain the material along the line. Under existing circumstances no estimate of the probable cost of tunnels on these different lines is possible, except upon wholesale assumptions of the character of the materials to be encountered. Such an estimate would really be but a conjecture and of no real value.

A pipe of requisite strength may be laid under the bottom line of the Bay, at a depth sufficient to give security against anchors.

The bottom having been found to be sand, gravel and mud of various degrees of consistency, it will be unsafe to lay down a rigid pipe, for such a pipe may be expected to settle unequally in materials of different powers of resistance. Unequal settlement would bring special strains on the connecting joints and endanger its integrity. Joints permitting some degree of motion would therefore be indispensable. A pipe with such joints is laid under the Schuylkill River. An example of more importance is that at Toronto, where a 36-inch pipe, 4,450 feet long, is laid on the bed of the Lake in a depth of 16 feet. The scale of this operation is the largest that is known to have been executed. In both instances the pipe is laid in fresh water. A short pipe is laid across a draw in a bridge in Boston harbor, in salt water. There is no known instance which approaches the line across the Bay in magnitude. The length of line, depth of water, and velocity of currents are all of unusual degree, and they combine in increasing the difficulty of success. We may however suppose the task to be successfully accomplished.

If extended from Oakland to San Francisco, the pipe would be five miles long. The risks of accident increase with the length of pipe. A short pipe could be readily replaced at small expenditure of time and money. The greatest depth of water in the Bay on this line is, in different positions, 60 and 70 feet. To say the least, it would be a difficult undertaking to repair

a breach at any such depth. It would probably often be impossible of accomplishment within the time required to exhaust the city reservoirs.

No coating exists which is known to protect iron from the corrosive action of sea water. Galvanizing lasts but for a few years. Bituminous coatings have not been tested sufficiently. Doubtless some protection against corrosion would be given by a covering of sand or mud to a depth of a few feet. It might be possible to sheath the pipe in a casing of wood which, if covered by mud, would not be destroyed by marine insects.

If such a protection were given there would still remain the objection that the pipe could not be conveniently reached and repaired.

Some security would be given by special tests of strength of the pipe; but with all possible precautions there would, nevertheless, be a feeling of insecurity, inseparable from the use of such a conduit.

The third proposition is to lay a cylindrical, wrought iron rigid tunnel in a trench, excavated to a depth of 25 feet or thereabouts below the bottom of the Bay. This tunnel is to be 10 or 11 feet in diameter. It follows the profile of the bottom, descending from the Oakland shore to the point of maximum depth near the San Francisco side; thence ascending to reach the land.

The tunnel is formed in sections of convenient length, to be connected in the trench by divers, who merely fasten the joints by placing bolts and turning the nuts. The joints are made by flanges on the inside of the pipe and are rigid. The outside is sheathed with wood.

The project has been worked out in detail by W. B. Hyde, C. E., the Engineer of the San Joaquin and San Francisco Water Company. The arrangements for handling and placing the pipe are by means of hydraulic power. Manual labor is reduced to a minimum. One cannot fail to admire the ingenuity which has provided special devices to meet all expected difficulties. The conduit is to be placed in the tunnel where it can be conveniently reached.

If a stable tunnel of this description were successfully laid, it might be, and probably would be, accepted as a suitable solution of the problem.

If a suitable foundation, of equal or nearly equal resistance, underlaid the Bay at the projected depth upon which the tunnel could be placed, there would be a reasonable assurance of stability. We are, however, entirely uninformed as to what materials underlie the bottom, except that at intervals over three miles of the line borings have been made to the depth of 25 feet. Soundings were also taken on the San Francisco water front by direction of the Harbor Commissioners some years ago, showing near the proposed line at or about Folsom street a depth of 60 to 70 feet of mud, underlaid by clay or sand. The borings made to 25 feet did not as a rule reach the solid material below; at least, those that were in mud—some of it approaching clay in consistency—stopped in this material, and we are not informed as to what is below.

PROFILE of INVERTED SYPHON *from* LIVERMORE PASS RESERVOIR *to* ROCK CREEK RESERVOIR.

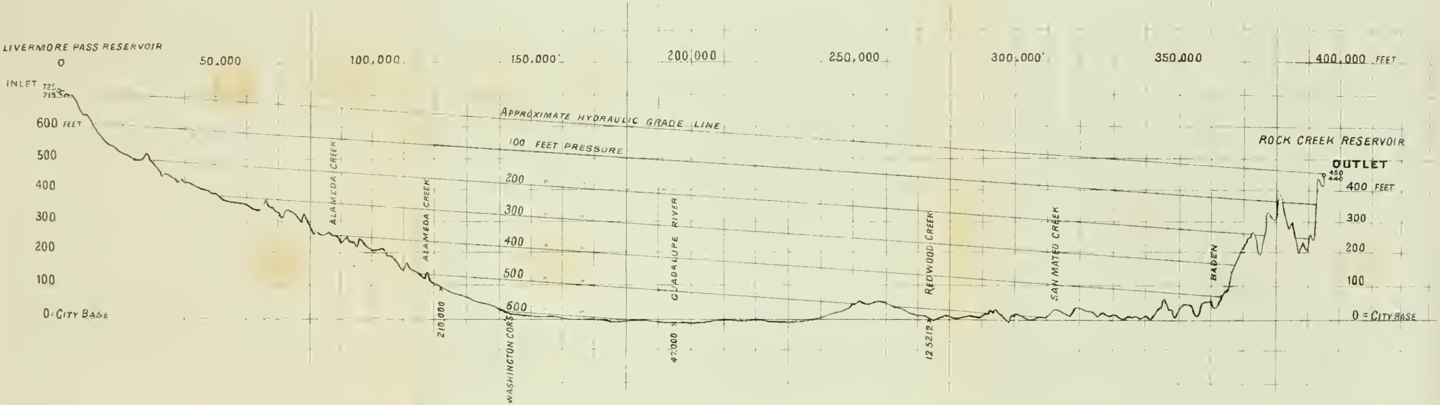
Around the head of the Bay.

Total length of Pipe 395.523 feet, Total fall 279 feet,

From Survey by T.R. Scowden, C.E. 1875.

Scale 1 inch to 40,000 feet Horizontal.

" " " " 400 " Vertical



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The bottom of the trench as explored by borings will be partly in sand, partly in gravel, with sections in soft mud and in more tenacious mud or clay. The resisting powers of these materials being unequal, with possible conditions below increasing this want of uniformity, it is thought that unequal settlement to an extent that cannot be anticipated must ensue.

The foundation, as far as we know it, is believed to be unstable for such a structure. Whether it would be possible to provide suitable foundation at any reasonable expense we do not know. It is believed that the material, whether mud or sand or gravel, should be bored and examined to the original bottom of the Bay, or if not to that extent at least until a thick stratum of clay, or what is vaguely called hard pan, is reached.

If we had the information that such an exploration would afford, it would be possible to speak more intelligently in regard to the feasibility of this project. The want of such detailed information makes it in a measure a duty to suppose the worst conditions to exist below, and necessarily throws very considerable doubt upon the project, which perhaps would be cleared off by fuller knowledge.

The consideration of foundation being vital, it cannot be necessary to enter into any detailed description or discussions of the appliances, by which the work is to be executed, or of the numerous details which it involves.

The foregoing brief discussion proves, if its conclusions are sound, that at present there is a serious element of doubt involved in all the propositions to pass the Bay. It may be repeated, that this doubt may be removed and reasonable conclusions may be reached by a proper expenditure of time and means.

Security is the first condition of a water supply. The calamity, attending a failure of the link of the conduit under the Bay, might be and probably would be of appalling magnitude. The loss of money might under possible circumstances be relatively an insignificant feature of the disaster. An actual famine is a possibility.

If this statement be reasonable, then security is worth whatever it may cost. It needs no argument to prove that security is best attained on the land. If the cost of supply carried all the way by land is admissible, the supply ought to come by land. If the burden be too great and it seems necessary to cross the Bay, then such full investigation ought to be made as will set all doubts at rest.

DESCRIPTION OF ROUTES BY WAY OF LIVERMORE PASS.

The routes from the South Fork of the American and from the Mokelumne cross over Livermore Pass.

The head of the pipe in the Mokelumne line is on the foot-hills of the Sierra Nevada, at an altitude of 1,206 feet. The Livermore Pass has an altitude of 739 feet. Between these points lies the San Joaquin Valley, which in its lowest point is but little above the high water sea level. This branch of the

conduit is, therefore, an inverted syphon which has a maximum pressure of 962 feet. The syphon is $62\frac{83}{100}$ miles in length. It will discharge into a reservoir at Livermore Pass having a capacity of 230 millions of gallons, as stated in Mr. Scowden's report.

From this reservoir to San Francisco the distance keeping on solid land is $74\frac{91}{100}$ miles. Crossing at Ravenswood the distance is 64 miles. This branch of the conduit is also an inverted syphon. The total length of the iron conduit is $137\frac{74}{100}$ miles, or by way of Ravenswood $126\frac{83}{100}$ miles.

The total fall from the head of the pipe to Livermore Pass is 467 feet, which corresponds to a fall of $7\frac{43}{100}$ feet per mile. Estimates have been made for a 40-inch and a 48-inch pipe on the Eastern syphon.

From Livermore Pass to the city estimates are made on pipes to carry the same quantities as are delivered at Livermore Pass. These estimates have been made to include different heights of delivery in San Francisco, the highest being 450 feet and the lowest 300 feet. They afford us the means of ascertaining the height which will be most advantageous. They are also made over the lines by way of Ravenswood. The diameters and fall vary in each of these cases, so that they are so many independent lines.

At the San Francisco terminus a reservoir is contemplated which will hold ten days' supply.

The difference of the estimates by way of the head of the Bay and by Ravenswood represents the value of a safe crossing at Ravenswood. The difference in length by these two routes is $10\frac{91}{100}$ miles. It is to be remarked, however, that this difference has not been found by actual survey but by measurements on our best maps. The line by the head of the Bay is kept on solid land. It is quite possible that it may be shortened by crossing portions of marsh land. This however may not be the case.

It may be repeated that the whole line from the foot-hills of the Sierra to the city ought to be located before construction is undertaken. There is reason to suppose that the line can be shortened to some extent and be placed on better ground. Either result will cheapen the construction.

The western syphon, which unites Livermore Pass and San Francisco, is common to the Mokelumne and the El Dorado lines. The portion of the eastern syphon which lies between the San Joaquin River and Livermore Pass is also common to both lines. At Johnson's Ferry on the San Joaquin the lines diverge; the Mokelumne route crossing the valley in the shortest line, while the El Dorado conduit crosses the valley obliquely. The latter line is consequently under heavy pressure for a longer distance than the Mokelumne conduit is.

The distance from the Borland reservoir, at the head of the El Dorado pipe line, to Livermore Pass is $82\frac{36}{100}$ miles which is $19\frac{53}{100}$ miles longer than the Mokelumne line. The total length of the conduit from Borland reservoir to San Francisco by head of Bay is $157\frac{27}{100}$ miles.

The fall per mile on the portion of the El Dorado line crossing the San Joaquin is $7\frac{12}{100}$ feet per mile. This fall is slightly less than that on the Mokelumne line. The pipe is therefore a trifle larger.

The line crosses the following named streams between the Borland reservoir and Livermore Pass, namely: French Camp Slough, Calaveras River, Mokelumne River, Jackson Creek, Dry Creek, Willow Slough, the Cosumnes River and the San Joaquin.

The Blue Lakes and Mokelumne line crosses French Camp Slough, Mormon Slough, the Calaveras and San Joaquin rivers, and some minor streams. None of these rivers are navigable except the San Joaquin. The latter may be crossed either by a pipe or by a tunnel.

The San Joaquin at the point of crossing is bordered by a belt of land, overflowed in extreme freshets for a distance of nine miles, unless protected by levees. A change of crossing may modify this distance. The estimates are made for bridging the whole distance, the river excepted.

The river at Johnson's Ferry is 350 feet between its banks, and 25 feet in maximum depth.

ROUTE OF CONDUIT FROM VICINITY OF AUBURN.

Cook's reservoir is the head of this line. It is situated nearly north from the town of Auburn, distant 2¾ miles. The pipe follows the line of the railroad as nearly as possible over a broken country, until Roseville is reached. At this point it leaves the Central Pacific Railroad and reaches the California Pacific at Davisville, crossing the Sacramento River in a line as nearly direct as possible. From Davisville it follows the Cal. P. R. R. to the town of Bridgeport, at which point it trends to the east, crossing Carquinez Straits between Benicia and Vallejo. Having crossed the Straits, the pipe ends in the Carquinez reservoir on the south shore of the Straits, at an altitude of 629 feet.

This portion of the line, from Cook's to Carquinez reservoir, is a reversed syphon 101 miles in length, the upper end having an elevation of 1,326 feet and the lower end 629 feet above city base.

The bottom of Carquinez Straits is 135 feet below the datum plane, so that the difference of level between the highest and lowest points of the conduit is 1,461 feet.

The second syphon branch of the conduit extends from Carquinez reservoir to the city, a distance of 32 miles. The lower end of this branch may be at any practicable altitude in San Francisco from the level of the sea to the extreme supposed point of delivery at Rock Creek reservoir, 450 feet in height.

The principal stream crossed by this line is the Sacramento river, with a

stretch of overflowed land, at times as much as 12 miles in width during extreme freshets, with 15 feet of water over considerable portions of the line. This is an unfavorable feature which perhaps might be lessened on a line from Cook's reservoir westward, crossing the Sacramento about ten miles above. This course would probably lengthen the line to some extent.

On the present line the estimates include bridging over the whole line, excepting the river proper.

Leaving the Sacramento bottom there are but two streams of importance on the remainder of the line namely, Cache and Puta Creeks.

A serious obstacle is Carquinez Straits ½ mile in width, which probably would be passed by a tunnel.

Carquinez reservoir, on the heights above the Straits, has a capacity, according to Mr. Scowden's report, of 504,000,000 gallons. The dam required to impound this quantity is excessive in height, being 194 feet.

This reservoir site is not recommended. It is used however for comparison of lines. A reservoir on this long line of pipe is almost indispensable. If the extent of the examinations proposed in the present inquiry had not been limited, search would have been made for a new site on one bank of the Straits or elsewhere on the line.

An approximate estimate is made of the cost of a line which does not rise to the top of the hills on the south side of the Straits, but keeps at an altitude of 200 feet above the sea, rejoining the surveyed line about seven miles nearer Oakland, at Fernandez landing.

No survey was made of this interval of seven miles, but approximate information was afforded as to the line by the survey of the Central Pacific Railroad, the results of which were furnished by Mr. Montague, Chief Engineer of the Railroad.

Between the Carquinez reservoir and Oakland the country is in part hilly, and partly a plain but little above the sea level. There are no special features on the line which require notice.

Arrived at Oakland, the pipe has the Bay of San Francisco to cross.

The length of the second syphon, reaching from Carquinez reservoir to the city, is 32 miles, making the total length of pipe from Cook's reservoir to San Francisco 133 miles.

The total length from Cook's reservoir, avoiding Carquinez reservoir, is $131\frac{63}{100}$ miles.

An estimate is also made on lines from Dutch Ravine reservoir, which is about nine miles nearer the city than Cook's reservoir. The altitude of the upper end of the pipe is 880 feet instead of 1,326 feet as at Cook's. The route from the Dutch Ravine reservoir to the city is the same as for the Cook's line. The lengths are, by way of Carquinez reservoir, $123\frac{84}{100}$ miles, and by way of shore of straits avoiding the reservoir $122\frac{44}{100}$ miles.

It will be remarked that the estimates for all lines crossing the bay are incomplete, in that they do not provide for the part of the line lying under the Bay. It has been explained in a previous part of this Report that it is quite impossible with present information to make an estimate of any value on this point.

The appended profiles of the various lines supply data with regard to the pressures and contours of the country which it is needless to repeat by description in words.

RESERVOIRS ON THE LINE.

The different reservoirs on the line have been mentioned in the preceding pages. In Table I they are arranged in systematic form, with classification of their principal features.

The last two in the table—Rich Gulch and Butte Valley—are on the canal line from the Mokelumne River, the former about 20 miles above the end of the pipe line, the latter within two miles of the same point. The tabulated data in respect to these two reservoirs are obtained from Mr. Scowden's report and maps.

The Borland and Dodson reservoirs are on the El Dorado line, near Latrobe.

The Cook reservoir and that at Dutch Ravine are on the Auburn line, at the head of the iron conduit. A third reservoir, at an altitude 200 feet higher than Cook's, was surveyed, but it is not included in this table.

These reservoirs, being at or near the head of the iron conduit, are intended to perform a double purpose: first, to settle the silt brought down by the canal; secondly, to maintain a supply, in case the flow in the canal is interrupted by breaches or by any other cause. The capacity of any of these reservoirs is in excess of present demands, and the reservoirs are adopted for purposes of comparison of different lines.

TABLE I.—RESERVOIRS AT OR NEAR THE HEAD OF PIPE LINES.

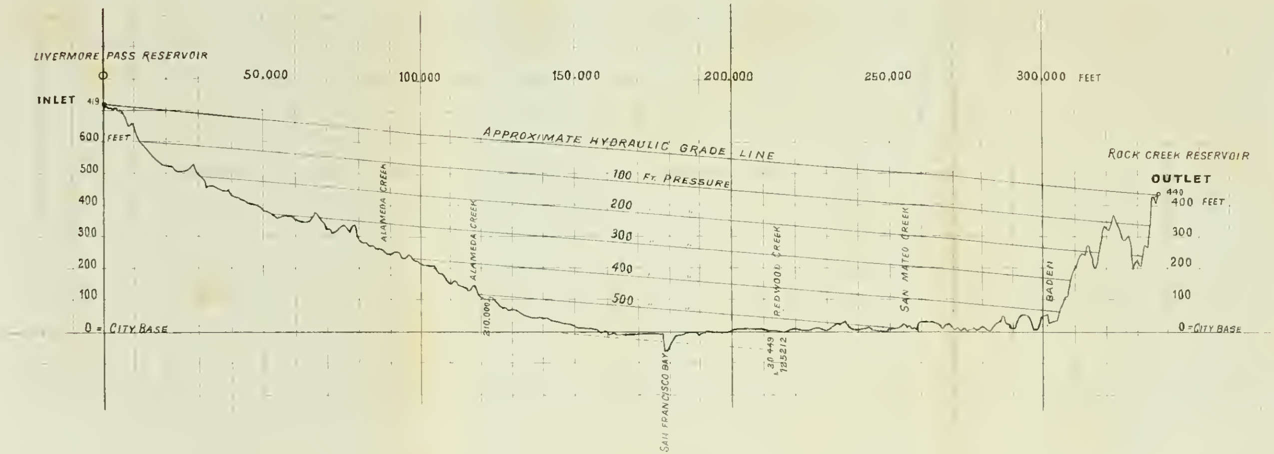
NAME.	LOCALITY.	ON WHICH LINE	DAM.					RESERVOIR.					
			Lowest Point above City Base in feet..........	Extreme Height......	Cubic Contents.......	Inner Slope Surface.		Above City Base.		Total Capacity.	Capacity above Discharge Pipe.	Area.	Circuit
						Area.	Cubic Contents. Stone Lining..	Surface of Water..	Discharge Pipe....				
				Ft.	Cu. Yds.	Sq. Yds.	Cu. Yds.	Feet.	Feet.	Gallons.	Gallons.	Acres.	Miles.
Borland Reservoir	Near Latrobe.	El Dorado Line.	....	...	....	....	....	1,350	1,325	1,187,925,000	952,500,000	186.41	3.89
Dam A.....	....	....	1,275	80	368,648	23,735	11,868	....	....	....	....	....	....
Dam B..........	....	....	1,312	43	136,523	12,931	6,466	....	....	....	....	....	....
Dodson Reservoir	Near Latrobe.	El Dorado Line.	....	....	....	....	....	985	940	1,425,562,500	1,237,687,500	129.70	1.96
Dam A..........	....	....	909	81	700,938	36,325	18,163	....	... ...	....	....	....	....
Dam B..........	....	....	982	58	510,196	31,111	15,555	....	....	....	....	....	... .
Cook Reservoir...	Near Auburn.	Lake Tahoe and South Yuba.	1301	77	318,169	18,553	9,277	1,373	1,326	947,062,500	858,375,000	117.99	2.24
Dutch Ravine R..	Near Auburn.	Lake Tahoe and South Yuba.	855	88	210,224	9,159	4,579	938	880	627,562,500	601,687,500	77.14	1.87
Rich Gulch R...	Near Mokelumne Hill.	Mokelumne Line.	....	....	120,000	9,333	4,666	2,063	....	....	175,000,000	25.50	....
Butte Valley R...	Near Mokelumne Hill.	Mokelumne Line.	....	....	408,600	12,200	6,100	1,276	....	....	500,000,000	77.00	1.86
Livermore Pass R.	Near Altamont.	El Dorado and Mokelumne	....	....	86,700	6,400	3,200	738	729	230,000,000	....	108.00	1.80

PROFILE of INVERTED SYPHON from LIVERMORE PASS RESERVOIR to ROCK CREEK RESERVOIR.

Total length of Pipe 337,915 feet, Total fall 279 feet,

From Survey by T. R. Scowden, C.E. 1875.

Scale 1 inch to 40,000 feet.



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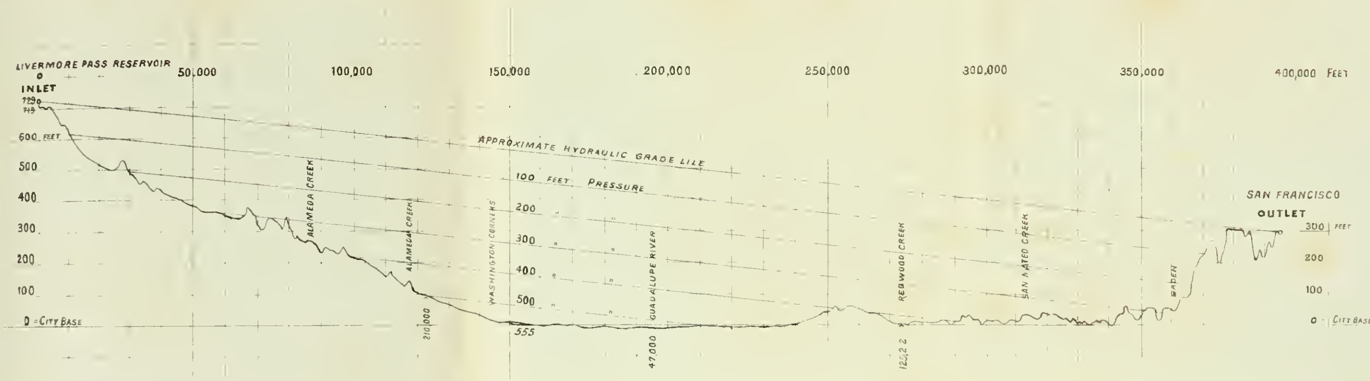
PROFILE of INVERTED SYPHON from LIVERMORE PASS RESERVOIR to SAN FRANCISCO

Around the head of the Bay.

Total length of Pipe 395.523 feet, Total fall 429 feet,

From Survey by T.R. Scowden, C.E. 1875

Scale 1 inch to 40,000 feet



THE ESTIMATES.

The estimates are given in tabular form for two different amounts of daily delivery. One amount is that estimated for a riveted 40-inch pipe with a fall of 7.43 feet per mile; the other is what is due to a 48-inch pipe with the same fall.

D'Arcy's formula for large pipes is

$$v = 113.8 \sqrt{r.\ s.}$$

in which

v is velocity in feet per second;
r is the hydraulic radius;
s a fraction representing the slope per mile.

The delivery of a 40-inch pipe, having the given fall, by this formula is 22,000,000 gallons per day, and of a 48-inch pipe is 34,500,000 gallons.

The formula was intended for smooth iron pipes, and not for pipes in which the interior surface is broken by rivet heads. In order to make sufficient allowance for these obstructions, the deliveries assumed in this discussion are those which would be given by a 38½-inch and a 46½-inch pipe respectively. One and one-half inches are thrown off from each diameter.

Some calculations of the actual delivery by riveted pipes in California go to indicate that in particular cases D'Arcy's formula does not give too large results, even with no allowance for obstruction of rivets. In Rochester, New York, with a riveted pipe D'Arcy's formula came below the actual delivery. Nevertheless it has been preferred to err if at all, on the side of safety, so that while it is not improbable that the 40-inch pipe may deliver 22,000,000, it is not assumed in this paper to exceed 20,000,000. The capacities of 40-inch and 48-inch riveted pipes are assumed to be those delivered by 38½-inch and 46½-inch smooth pipes, as computed by D'Arcy's formula, namely: 20,000,000 and 32,000,000 gallons per day respectively.

The estimates of the conduit relate to the delivery of these quantities from each of the sources of supply.

The fall per mile being different in each of these routes, the size of the pipe is different in each case.

Inasmuch as different routes of conduit are open to choice, estimates are given for these, as for instance: Around the head of the Bay and by way of Ravenswood; or, for the Auburn line, by way of Carquinez reservoir and by a route avoiding the reservoir. The latter line has two sets of estimates, starting with different elevations: one from Cook's reservoir and one from Dutch Ravine, 446 feet lower.

These lines are also calculated for different elevations in the city, namely: for 450 feet, for 300 feet, 200 feet and 100 feet.

These different calculations are all independent. They involved a great amount of labor, but they seemed to be required to meet all points of reasonable inquiry.

The tabular estimates are confined to the construction and laying of the iron conduit, including such reservoirs as have been surveyed and as are essential for the service.

The iron is placed at $80 per ton, about $10 in advance of current rates, which however are extremely low and subject to a rise at any time. The manufacture of the pipe is placed at $27.50 per ton.

It is expected that the manufacture will be carried on in special shops, established on the water front of the Bay or on the lines of railroad, where the material will be received and sent away with the minimum charge for cartage and handling.

The shops can, under an order of this magnitude, be equipped with labor-saving appliances and tools, which do not now exist in any iron works in the city. These special arrangements must necessarily result in a very considerable reduction in the cost of this kind of work, and it is believed that the cost can be reduced below the estimate.

The distribution of the pipe along the line is of itself a problem of considerable magnitude. It has been worked out with care and in detail. The distance every ton must travel, whether by rail, by boat or by wagon, has been calculated. The tariff rates by public transportation, and twenty-five cents per ton per mile in the plains, and fifty cents per ton per mile in the hills by wagon, are the governing prices. To the sum total $1.62 per ton is added for handling and contingencies.

The trench for the pipe is assumed to be for twenty miles in rock, the remainder in earth excavation. There is something assumed in this calculation, as the facts are not accurately known.

The estimates for bridges include all overflowed lands as well as bridges over streams not navigable. It is not, however, supposed that this extent of bridging will be necessary. The bridges of any considerable span are estimated for masonry piers and Howe truss.

The foregoing remarks are deemed necessary to explain the character of the estimates, which are by design intended to be full. At present prices it is believed that the line can be laid down under the estimates.

The height of delivery in San Francisco is a very important point.

A little reflection makes it plain that with syphons for conduits the cost must increase with the height of the outlet. Take for instance the Blue Lakes or Mokelumne line of 20,000,000 around the Bay:

With an outlet 450 feet high the cost is..............	$11,639,377
With an outlet 300 feet high the cost is..............	10,193,480
Difference.	$1,445,897

With an outlet 200 feet high the cost is $9,660,700, less by $532,780 than for 300 feet.

There is a height of delivery which is more advantageous in an economical point of view than any others, whether above or below. Some further study will be necessary to fix exactly where this point is; but an easy calculation will show that as between 300 feet and 450 feet, the former is to be preferred for economical reasons.

The quantity of water which now comes from San Andreas is two-thirds of the city supply. It is delivered at College Hill reservoir, at an altitude of

255 feet. Pillarcitos reservoir supplies Lake Honda with a quantity between two and three millions of gallons a day. Lake Honda has an elevation of 377 feet. The pumps at Black Point supply the Upper Russian Hill reservoir, altitude 300 feet, and lower reservoir, altitude 140 feet, each say with a million a day.

The total amount now delivered in the city, at an elevation of 300 feet or more, is what goes into Lake Honda and Upper Russian Hill reservoir, not to exceed 4,000,000 of gallons a day. Lake Honda has connection with the lower systems, and all of its water is not consumed in the high service.

Let us suppose, however, that five of the 20 millions delivered at 300 feet height are required at an elevation of 450 feet—which it will be remarked is 73 feet above Lake Honda, and probably 100 feet above an existing service in the city—and thus that pumps come into requisition.

The cost of pumping 5,000,000 gallons a day 150 feet high—at 17 cents for 1,000,000, raised one foot—is per day $127.50, or per year $46,537.50, which includes wear and tear and interest on original cost of pumps. The difference of capital cost of 300 feet and 450 feet elevation in delivery is $1,435,897, the interest at 6 per cent. being $86,153.82. Difference between $86,153.82 and $46,537.50 is $39,616.32, which is the yearly saving.

This statement embraces circumstances much more unfavorable than those that exist, or are likely to exist; for it supposes all of the 5,000,000 gallons to be pumped 150 feet, whereas, even if water were required at this height of 450 feet, much the greater part pumped would be consumed between 300 feet and 450 feet, and only a small fraction would reach the tank at the extreme elevation. Seventeen cents for pumping is a high price.

So, even an extreme case proves the truth of the proposition—namely, that it will be more economical to deliver the whole quantity at 300 feet, and pump whatever may be required at higher levels, than to deliver the whole at an elevation of 450 feet. The case is still stronger for a pipe delivering 32,000,000 gallons daily.

The question of city distribution is involved in the determination of the most economical point of delivery. This question, owing to the irregular topography of the city, is one of considerable magnitude and complexity, and one that it has not been possible to consider up to this time. It is not, therefore, possible to state with exactness the proper elevation of delivery. We may, however, rest in the opinion that it will not much exceed 300 feet, if indeed it turns out to be so high.

The estimates show the relation of a tunnel at Ravenswood, and the line around the head of the bay. For a delivery 300 feet high—taking the Blue Lakes for comparison—the cost of 20,000,000 gallons a day by way of head of Bay exceeds the cost by Ravenswood, the tunnel estimate not included, $811,691. For 32,000,000 gallons the difference is $1,089,148. These differences represent a limit of cost which the tunnel cannot exceed and be an economical measure.

The lines of conduit are all estimated to terminate at Rock Creek reservoir,

that is, the lengths are estimated to this point in every case whatever the height may be.

The only lines of supply under consideration, which can reach San Francisco entirely by land, are those which cross Livermore Pass and head the Bay. In our present state of information in regard to the strata underlying the Bay, it is quite impossible to express an opinion in regard to the cost of a tunnel, its practicability, or the time which it would require in construction. This condition of our knowledge limits us at present to a choice between the lines from the *Mokelumne* and from the *South Fork of the American.*

The estimates of these lines are respectively for different quantities delivered 300 feet high as follow, namely:

From the *Mokelumne*, by way of the *head of the Bay*—

20 millions per day	$10,193,480.
32 millions per day	14,111,733.

From the *South Fork of the American*—

20 millions per day	$12,306,384.
32 millions per day	16,997,858.

These estimates include the conduit from the end of the canal, and the reservoirs at the heads of the pipes and at Livermore Pass. They do not include the water rights, the cost of reservoirs in the mountains, the canals connecting the rivers and the heads of the pipe lines, a terminal reservoir in San Francisco, the distribution system in the streets of the city, nor the right of way.

It has already been remarked, that a properly proportioned distribution system, to conform to the widely different levels, is a special problem of magnitude, the consideration of which must be deferred for future study. It is a factor common to all the projects, although not probably identical in each case.

It will be noticed further on in this report, that the value of the existing pipe system in the streets of San Francisco is less than $2,000,000. Inasmuch as it is the ultimate purpose of this report to bring the different projects to a comparison of cost, we assume the sum of $3,000,000 to represent the expense of providing terminal arrangements in the city, capable of supplying a daily demand of 12 or 13 millions of gallons, which is about the amount stated to be supplied by the Spring Valley system. In this amount is included a reservoir capacity of 250 millions of gallons, which is 10 or 12 days supply for the smaller of the proposed conduits.

The canal surveyed originally by Mr. Scowden and again proposed by W. V. Clark, from the Mokelumne, is 51¾ miles in length. Mr. Clark offers to construct this canal with a capacity at its lower end of 100,000,000 gallons per day, for the sum of $1,600,000. The new line which has been examined is 38 miles in length and its cost, at the same rate per mile, ought not to exceed $1,200,000.

A similar canal from the South Fork of the American to the Borland reser-

voir, 45 miles long, is offered by the El Dorado W. & D. G. M. Company for $1,250,000. For a conduit of 32 millions of gallons, a minimum storage of 3,000 millions will be indispensable. This can be secured by the existing dam at the Upper Lake and a new dam to be constructed at Upper Bear River Reservoir. A permanent dam at the latter point will cost by our estimate $346,500.

It is estimated that a suitable masonry dam, with gate-house, can be built at Silver Lake for $100,000, provided no unexpected difficulties are encountered.

Summing up these items, we have for the *Mokelumne Line:*

32 millions conduit	$14,108,632
Upper Bear River Reservoir	346,500
Canal	1,200,000
Terminal reservoir and Distribution System	3,000,000
Capital cost of thirty-two millions of gallons daily	$18,655,132
Capital cost of one million of gallons daily	$582,973

To which are to be added the cost of franchises, right of way, and interest during construction.

From the *South Fork of the American* the corresponding items are as follows, namely:

Conduit	$16,997,853
Silver Lake reservoir	100,000
Canal	1,250,000
Terminal reservoir and Distribution	3,000,000
Capital cost of thirty-two millions of gallons daily	$21,347,853
Capital cost of one million of gallons daily	$667,120

For 20 millions from the *Mokelumne*, everything being the same as just stated, except the conduit, the cost will be $14,739,980.

The same daily amount from the *South Fork of the American* represents a capital cost of $16,656,384.

This estimate provides for a complete independent system. If, however, the Spring Valley Works were the property of the city, the arrangements might be made to correspond. The delivery might then be made to the San Andreas or the Crystal Springs reservoir in San Mateo County, or into any of the existing service reservoirs in the city. The cost of the terminal reservoir and of the distribution system would become needless, except so far as the distribution system of the Spring Valley Company may need enlargement and modification.

Three years will be required to put these lines in operation. Supposing bonds to be issued uniformly during construction, the interest will be that of the whole cost for one and one-half years, or 9 per cent., which it is fair to charge to the construction account. Adding 9 per cent. the estimates become: For the *Mokelumne line,* with 20 and 32 millions, respectively $16,066,578 and $20,334,094; for the *American line* the corresponding amounts are $18,155,458 and $23,269,160.

With these statements of capital outlay, we are prepared to ascertain the resulting cost of a thousand gallons from either of these sources, by conduits carrying either 20 or 32 millions of gallons daily, at a period when the consumption equals the delivery of the conduits.

The yearly interest at 6 per cent. on the cost—$20,334,094—of the *Mokelumne line* of 32,000,000 gallons is $1,213,446. This represents a yearly delivery of 11,680,000,000 gallons. The cost of a thousand gallons is $10\frac{4}{10}$ cents. If we admit the conduit to carry 34,000,000 gallons per day, the cost per thousand gallons will be $9\frac{8}{10}$ cents.

A similar calculation for the *South Fork of the American* will show the cost per thousand gallons by a 32,000,000 conduit to be 12 cents, or carrying 34,000,000, the price will be $11\frac{3}{10}$ cents. For a conduit carrying 20,000,000, the cost will be $14\frac{9}{10}$ cents, or allowing 22,000,000 the cost will be $13\frac{1}{2}$ cents.

The cost of a thousand gallons from the *Mokelumne* by a 20,000,000 conduit is $13\frac{2}{10}$ cents, or allowing 22,000,000 the cost will be 12 cents.

It will be observed that the cost per thousand gallons becomes less as the size of the conduit is increased.

This calculation takes no account of a sinking fund for the redemption of the bonded indebtedness, nor does it include what may be required for the yearly extension of the distribution system, or for the expense of administration. This extension will be required as the city increases, whatever source affords the supply of water, and its cost will be about the same in each case. It is, therefore, not an essential element in the comparison of different projects.

It will be borne in mind that the present Board of Commissioners have made no surveys on the Mokelumne line, and that the data upon which the estimates of this line are based, as well as a large part of the other lines, are derived from the survey of 1874. This fact and the further circumstance that none of the lines have been located, prevent such a full and detailed estimate on minor points as would be desirable. It seems quite probable, from a study of the maps and partial reconnoissance by barometer, that the Mokelumne conduit may be located on a better and a somewhat shorter and cheaper line, than that followed by the preliminary survey. On the other hand, it may turn out that the cost of some of the reservoirs on the line may prove to be larger than the estimates, which are nearly those made in 1874. We are also but partially informed as to the character of the excavation in the trenches, or of the nature of the protection which it may be necessary to give

to the conduit, in passing roads over which heavy loaded teams pass. The remarks, which were made on the desirability of another and shorter canal line, in the discussion of the Mokelumne project, indicate a possible saving of several hundred thousand dollars under that head.

In such a broad and general treatment as the discussion of so many projects requires, it is quite impossible to be definite and positive on all the features, small as well as great. There seems to be quite as much probability of shortening and cheapening the line by possible changes of location, as there is that the lesser features which have not received full investigation will swell the cost above the estimates.

A possible change of location of importance is from Suñol Station to Mission San José. The route of the survey now goes by Niles Station, making a detour of several miles. A much more direct route is possible. It will require a tunnel but will save several miles of conduit, place this part of the line under lighter pressure, and add an appreciable quantity to the capacity of the conduit, which are three independent benefits, making in the aggregate a point of considerable magnitude—to the value of $100,000 and perhaps $200,000. This saving applies equally to all lines crossing Livermore Pass and heading the Bay.

The maps indicate the possibility of making some minor changes to the improvement of the line in the San Joaquin Valley.

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MOKELUMNE LINE.—TABLE OF COST OF A CONDUIT CARRIED OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 20 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF HEAD OF PIPE=1206 FEET. ELEVATION OF LIVERMORE PASS=739 FEET.

	Length.		Diameter of Pipe in Inches.	Height of Delivery above City base in Feet.	Iron at $80.00 per ton of 2000 lbs.		Rivets at $120 per ton of 2000 lbs.		Shopwork, manufacturing, testing and coating, at $27.50 per ton of Plates	Excavating Trench for Pipe, Joint-holes, Laying Pipe, Ramming, Filling, etc.						
										Earth.			Rock.			Total Cost for Excavation.
	Miles.	Feet.			Tons.	Cost.	Tons.	Cost.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay...	62.83	331,748	40.	....	......	....	......	....	....	284,356	.51	$145,021	47,392	$1.03	$48,814	$193,835
	74.91	395,523	45.94	....	... .	......	....	....	... .	339,020	.61	206,802	56,503	1.14	64,413	271,215
Totals...............	137.74	727,271	......	450	73,129	$5,850,320	4,022	$482,640	$2,011,047	623,376	......	351,823	103,895	......	113,227	$465,050
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay....	62.83	331,748	40.	....	.....	....	......	....	....	284,356	.51	145,021	47,392	1.03	48,814	193,835
	74.91	395,523	42.13	....	......	....	.....	....	....	339,020	.53	179,680	56,503	1.05	59,328	239,008
Totals..............	137.74	727,271	......	300	63,029	5,042,320	3,466	415,920	1,733,297	623,376	......	324,701	103,895	......	108,142	432,843
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay ...	62.83	331,748	40.	....	......	....	......	....	....	284,356	.51	145,021	47,392	1.03	48,814	193,835
	74.91	395,523	40.41	....	......	....	......	....	....	339,020	.51	172,900	56,503	1.03	58,198	231,098
Totals...............	137.74	727,271	.....	200	58,699	4,695,920	3,228	387,360	1,614,222	623,376	.....	317,921	$103,895	......	107,012	424,933
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay...	62.83	331,748	40.	....	......	....	......	....	....	284,356	.51	145,021	47,392	1.03	48,814	193,835
	74.91	395,523	39.09	....	......	....	......	....	....	339,020	.50	169,510	56,503	1.01	57,068	226,578
Totals	137.74	727,271	......	100	55,027	4,402,160	3,026	363,120	1,513,242	623,376	......	314,531	103,895	......	105,882	420,413

MOKELUMNE LINE.—TABLE OF COST OF A CONDUIT CARRIED OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 20 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF HEAD OF PIPE 1206 FEET. ELEVATION OF LIVERMORE PASS 739 FEET—CONTINUED.

	Mechanical Work on Pipe in the Trench, Riveting, Painting, Handling, etc.			Manholes, Blow-offs, Air-valves, Gates, etc.	Distribution of Pipes including Cartage, Loading and Unloading, Railroad and Steamer Freights.			Bridges and Piling.	Extra work crossing the San Joaquin River	Livermore Reservoir	Butte Valley Reservoir.	Telegraph Line at $250 per mile	Total Cost.	Total Cost with 10 per cent added for Contingencies
	Feet.	Cost per Foot.	Cost.	Cost.	Tons of Pipe Coated.	Cost per Ton.	Cost.	Cost.	Cost.	Cost.	Cost.	Cost.	Dollars.	Dollars.
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay ...	331,748 395,523	.60 .80	$199,049 316,418											
Totals ...	727,271		515,467	$87,272	80,237	$6 00	$181,422	$341,625	$20,000	$60,680	$231,294	$34,435	10,581,252	11,639,377
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay ...	331,748 395,523	.60 .64	199,049 253,135											
Totals ...	727,271		452,184	87,272	69,155	6.00	414,930	341,625	20,000	60,680	231,294	34,435	9,266,800	10,193,480
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay ...	331,748 395,523	.60 .60	199,049 237,314											
Totals ...	727,271		436,363	87,272	64,404	6 00	386,424	341,625	20,000	60,680	231,294	34,435	8,782,455	9,660,700
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay ...	331,748 395,523	.60 .60	199,049 237,314											
Totals ...	727,271		436,363	87,272	60,375	6 00	362,250	341,625	20,000	60,680	231,294	34,435	8,272,854	9,100,139

MOKELUMNE LINE.—TABLE OF COST OF A CONDUIT CARRIED OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 20 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF HEAD OF PIPE=1206 FEET. ELEVATION OF LIVERMORE PASS =739 FEET—CONTINUED.

	Length.		Diameter of Pipe in Inches.	Height of delivery above City base in Feet.	Iron at $80.00 per ton of 2000 lbs.		Rivets at $120 per ton of 2000 lbs.		Shopwork, manufacturing, testing and coating at $27.50 per ton of Plates	Excavating Trench for Pipe, Joint-holes, Laying Pipe, Ramming, Filling, etc.						
										Earth.			Rock.			Total Cost for Excavation.
	Miles.	Feet.			Tons.	Cost.	Tons.	Cost.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	62.83 64.	331,748 337,920	40. 44.50	....	....	... .	....	....	....	284,356 289,646	.51 .60	$145,021 173,788	47,392 48,274	$1.03 1.12	$48,814 54,067	$193,835 227,855
Totals	126.83	669,668	......	450	64,677	$5,174,160	3,628	$435,360	$1,778,617	574,002	......	318,809	95,666	......	102,881	421,690
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	62.83 64.	331,748 337,920	40. 40.84	....	....	....	....	....	....	284,356 289,646	.51 .52	145,021 150,616	47,392 48,274	1.03 1.01	48,814 50,205	193,835 200,821
Totals...............	126.83	669,668	... ..	300	56,836	4,546,880	3,125	375,000	1,562,990	574,002	......	295,637	95,666	.....	99,019	394,656
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	62.83 64.	331,748 337,920	40. 39.15	....	....	....	....	....	. ...	284,356 289,646	.51 .50	145,021 144,823	47,392 48,274	1.03 1.01	48,814 48,757	193,835 193,580
Totals.........	126.83	669,668	......	200	53,250	4,260,000	2,928	351,360	1,464,365	574,002	......	289,844	95,666	......	97,571	387,415
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood. ..	62.83 64.	331,748 337,920	40. 37.84	... .	....	....	....	....	....	284,356 289,646	.51 .46	145,021 133,237	47,392 48,274	1.03 .92	48,814 44,412	193,835 177,649
Totals...............	126.83	669,668	......	100	50,815	4,065,200	2,794	335,280	1,397,413	574,002	.....	278,258	95,666	......	93,226	371,484

MOKELUMNE LINE.—TABLE OF COST OF A CONDUIT CARRIED OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 20 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF HEAD OF PIPE =1206 FEET. ELEVATION OF LIVERMORE PASS =739 FEET—CONCLUDED.

	Mechanical Work on Pipe in the Trench, Riveting, Painting, Handling, etc.			Manholes, Blow-offs, Air-valves, Gates, etc..........	Distribution of Pipes including Cartage, loading and unloading, Railroad and Steamer freights.			Bridges and Piling.	Extra work crossing the San Joaquin River....	Livermore Reservoir..	Butte Valley Reservoir.	Telegraph Line at $250 per mile..............	Total Cost.	Total Cost with 10 per cent. added for Contingencies..........
	Feet.	Cost per Foot.	Cost.	Cost.	Tons of Pipe Coated.	Cost per Ton.	Cost.	Cost.	Cost.	Cost.	Cost	Cost.	Dollars.	Dollars.
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	{ 331,748 { 337,920	.60 .67	$199,049 226,406	....	....	....	....	....	....	....	....	....	....	....
Totals................	669,668	......	425,455	$80,360	71,037	$6 00	$426,222	$380,495	$20,000	$60,680	$231,294	$31,708	9,466,011	10,412,645
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	{ 331,748 { 337,920	.60 .62	199,049 209,510	33,175 33,792	....	....	....	....	....	....	....	....	....	....
Totals................	669,668	......	408,559	66,967	62,359	6 00	374,154	380,495	20,000	60,680	231,294	31,708	8,453,382	9,298,720
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	{ 331,748 { 337,920	.60 .59	199,049 199,273	33,175 33,792	....	....	....	....	....	....	....	....	....	....
Totals................	669,668	......	398,322	66,967	58,425	6 00	350,550	380,495	20,000	60,680	231,294	31,708	7,771,862	8,549,048
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	{ 331,748 { 337,920	.60 .55	199,049 185,856	33,175 30,413	....	....	....	....	....	....	....	....	....	....
Totals................	669,668	......	384,905	63,588	55,753	6 00	334,518	380,495	20,000	60,680	231,294	31,708	7,732 318	8,505,550

LINE FROM THE SOUTH FORK OF THE AMERICAN RIVER.—TABLE OF COST OF A CONDUIT FROM BORLAND'S RESERVOIR OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 20 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF BORLAND'S RESERVOIR=1325 FEET. ELEVATION OF LIVERMORE PASS=739 FEET.

	Length.		Diameter of Pipe in Inches........	Height of deliv'ry above City Base in Feet.	Iron at $80.00 per ton of 2000 lbs.		Rivets at $120 per ton of 2000 lbs.		Shopwork, manufacturing, testing and coating, at $27.50 per ton of Plates.......	Excavating Trench for Pipe, Joint-holes, Laying Pipe, Ramming, Filling, etc.						
										Earth.			Rock.			Total Cost for Excavation.
	Miles.	Feet.			Tons.	Cost.	Tons.	Cost.	Cost.	Lineal Feet.	Cost per Foot	Cost.	Lineal Feet.	Cost per Foot.	Cost.	
Borland's Reservoir to San	82.36	434,855	40.34	......	......	....	......	....	....	377,534	$ .52	$196,318	57,326	$1.04	$59,619	....
Francisco, *via* Head of Bay.	74.91	395,523	45.94	......	......	....	......	....	....	347,251	.61	211,823	48,274	1.14	55,032	....
Totals.........	157.27	830,378	......	450	86,354	$6,908,320	4,744	$569,280	$2,374,735	724,785	......	408,141	105,600	......	114,651	$522,792
Borland's Reservoir to San	82.36	434,855	40.34	......	......	....	......	....	....	377,534	.52	196,318	57,326	1.04	59,619	....
Francisco, *via* Head of Bay.	74.91	395,523	42.13	......	......	....	......	....	....	347,251	.53	184,043	48,274	1.05	50,688	....
Totals................	157.27	830,378	......	300	76,154	6,092,320	4,188	502,560	2,094,235	724,785	......	380,361	105,600	......	110,307	490,668
Borland's Reservoir to San	82.36	434,855	40.34	......	......	....	......	....	....	377,534	.52	196,318	57,326	1.04	59,619	....
Francisco, *via* Head of Bay.	74.91	395,523	40.41	......	......	....	......	....	....	347,251	.52	180,570	48,274	1.04	50,205	....
Totals................	157.27	830,378	......	200	71,824	5,745,920	3,950	474,000	1,975,160	724,785	......	376,883	105,600	......	109,824	486,712
Borland's Reservoir to San	82.36	434,855	40.34	......	......	....	......	....	....	377,534	.52	196,318	57,326	1.04	59,619	....
Francisco, *via* Head of Bay.	74.91	395,523	39.09	......	......	....	......	....	....	347,251	.50	173,625	48,274	1.00	48,274	....
Totals................	157.27	830,378	......	100	68,154	5,452,320	3,748	449,760	1,874,235	724,785	..	369,943	105,600	......	107,893	477,836
Borland's Reservoir to San	82.36	434,855	40.34	......	......	....	......	....	....	377,534	.52	196,318	57,326	1.04	59,619	......
Francisco, *via* Ravenswood	64.00	337,920	44.50	...	......	....	......	....	....	289,646	.60	173,788	48,274	1.12	54,067	....
Totals................	146.36	772,775	......	450	77,802	6,224,160	3,894	467,280	2,139,555	667,180	......	370,106	105,600	......	113,686	483,792
Borland's Reservoir to San	82.36	434,855	40.34	......	......	....	......	....	....	377,534	.52	196,318	57,326	1.04	59,619	....
Francisco, *via* Ravenswood	64.00	337,920	40.84	......	......	....	......	....	....	289,646	.53	153,512	48,274	1 05	50,688	....
Totals................	146.36	772,775	......	300	69,961	5,596,880	3,498	419,760	1,923,927	667,180	......	349,830	105,600	.....	110,307	460,137

LINE FROM THE SOUTH FORK OF THE AMERICAN RIVER.—TABLE OF COST OF A CONDUIT FROM BORLAND'S RESERVOIR OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 20 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF BORLAND'S RESERVOIR=1325 FEET. ELEVATION OF LIVERMORE PASS=739 FEET.—CONCLUDED.

	Mechanical Work on Pipe in the Trench, Riveting, Painting, Handling, etc.			Manholes, Blow-offs, Air-valves, Gates, etc......	Distribution of Pipes including Cartage, Loading and Unloading, Railroad and Steamer Freights.			Bridges and Piling.	Extra work crossing the San Joaquin River......	Livermore Reservoir..	Borland's Reservoir.	Telegraph Line at $250.00 per mile...	Total Cost.	Total Cost with 10 per cent. added for Contingencies....
	Feet.	Cost per Foot.	Cost.	Cost	Tons of Pipe Coated.	Cost per Ton.	Cost.	Cost.	Cost.	Cost.	Cost.	Cos .	Dollars.	Dollars.
Borland's Reservoir to San Francisco, *via* Head of Bay.	434,855 395,523	$ .62 .80	$269,610 316,418	$43,485 47,462										
Totals................	830,378	......	586,028	90,947	94,741	$6 00	$568,446	$456,907	$20,000	$60,680	$319,867	$39,318	12,547,320	13,802,052
Borland's Reservoir to San Francisco, *via* Head of Bay.	434,855 395,523	.62 .64	269,610 253,135	43,485 43,507										
Totals................	830,378	......	522,745	86,992	83,555	6 00	501,330	456,907	20,000	60,680	319,867	39,318	11,187,622	12,306,384
Borland's Reservoir to San Francisco, *via* Head of Bay.	434,855 395,523	.62 .62	269,610 245,224	43,485 39,523										
Totals................	830,378	......	514,834	83,008	78,805	6 00	472,830	456,907	20,000	60,680	319,867	39,318	10,649,236	11,714,160
Borland's Reservoir to San Francisco, *via* Head of Bay.	434,855 395,523	.62 .56	269,610 221,493	43,485 39,523										
Totals................	830,378	......	491,103	83,008	74,778	6 00	448,668	456,907	20,000	60,680	319,867	39,318	10,173,702	11,191,072
Borland's Reservoir to San Francisco, *via* Ravenswood	434,855 337,920	.62 .67	269,610 226,406	43,485 37,171										
Totals..............	772,775	......	496,016	80,655	84,968	6 00	509,808	495,407	20,000	60,680	319,867	36,590	11,333,810	12,467,191
Borland's Reservoir to San Francisco, *via* Ravenswood	434,855 337,920	.62 .63	269,610 212,890	43,485 33,792										
Totals...............	772,775	......	482,500	77,277	76,397	6 00	458,382	495,407	20,000	60,680	319,867	36,590	10,351,407	11,386,548

AUBURN LINE.—TABLE OF COST OF A CONDUIT DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 20 MILLIONS OF GALLONS PER DAY, BY VARIOUS ROUTES THROUGH OAKLAND, FROM COOK'S RESERVOIR, (HEIGHT 1326 FEET,) THE COST OF TUNNELS UNDER THE BAY OF SAN FRANCISCO, AND STRAITS OF CARQUINEZ NOT BEING INCLUDED.

	Length.		Diameter of Pipe in Inches..	Height of deliv'ry above City Base, in Feet..........	Iron at $80.00 per ton of 2,000 lbs.		Rivets at $120 per ton of 2,000 lbs.		Shopwork, manufacturing, testing, coating, at $27.50 per ton of Plates..........	Excavating Trench for Pipe, Joint-holes, Laying Pipes, Ramming, Filling, Etc.						
										Earth.			Rock.			Total Cost of Excavation.
	Miles	Feet.			Tons.	Cost.	Tons.	Cost,	Cost.	Lineal Feet.	Cost per Foot.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	
Cook's Reservoir to San Francisco, *via* Carquinez	101.00	533,280	40.48	.....	......	....	......	....	....	452,496	$ .52	$235,298	80,784	$1.04	$84,015	... .
Reservoir..............	32.00	168,960	42.88	......	.....	....	......	....	....	144,144	.56	80,721	24,816	1.08	26,801	....
Totals...............	133.00	702 240	......	450	74,949	$5,995,920	4,364	$523,680	$2,061,098	596,640	......	316,019	105,000	......	110,816	$426,835
Cook's Reservoir to San Francisco, *via* Carquinez	101.00	533,280	40.48	......	......	....	......	....	....	452,496	.52	235,298	80,784	1.04	84,015	....
Reservoir...............	32.00	168,960	37.48	......	.....	....	......	....	....	144,144	.48	69,189	24,816	0.98	24,319	....
Totals...............	133.00	702,240	......	300	69,922	5,593,760	3,845	461,400	1,922,855	596,640	......	304,487	105,000	......	108,334	412,821
Cook's Reservoir to San Francisco, *via* Carquinez	101.00	533,280	40.48	......	......	....	......	....	....	452,496	52	235,298	80,784	1.04	84,015	....
Reservoir................	32.00	168,960	35.54	......	......	....	.....	....	....	144,144	.44	63,423	24,816	0 95	23,375	....
Totals...............	133.00	702,240	... ..	200	68,218	5,457,440	3,752	450,240	1,875,995	596,640	......	298,721	105,600	......	107,390	406,111
Cook's Reservoir to San Francisco, *via* Carquinez	101.00	533,280	40.48	......	......	....	......	....	....	452,496	.52	235,298	80,784	1.04	84,015	....
Reservoir.........	32.00	168,960	34.09	......	......	....	.. ..	....	....	144,144	.41	59,099	24,816	0.92	22,831	....
Totals...............	133.00	702,240	......	100	66,789	5,343,120	3,673	440,760	1,836,698	596,640	.....	294,397	105,600	......	106,846	401,243
Cook's Reservoir to San Francisco, *via* Shore Line.	....	....	39.64	......	......	....	......	....	....	....	......	....	....	......	....	....
Totals...............	131.63	695,006	......	300	65,503	5,240,240	3,603	432,360	1,801,333	589,406	.50	284,703	105,000	1.02	107,702	392,409

AUBURN LINE.—TABLE OF COST OF A CONDUIT DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 20 MILLIONS OF GALLONS PER DAY, BY VARIOUS ROUTES THROUGH OAKLAND, FROM COOK'S RESERVOIR, (HEIGHT=1326 FEET,) THE COST OF TUNNELS UNDER THE BAY OF SAN FRANCISCO AND STRAITS OF CARQUINEZ NOT BEING INCLUDED.—CONCLUDED.

	Mechanical Work on Pipe in the Trench, Riveting, Painting, Handling, etc.			Manholes, Blow-offs, Air-valves, Gates, etc.	Distribution of Pipes, including Cartage, Loading and Unloading, Railroad and Steamer Freight.			Bridges and Piling.	Extra work crossing the Sacramento river	Cook's Reservoir.....	Carquinez Reservoir.	Telegraph line at $250 per mile.....	Total Cost.	Total cost with 10 per cent added for contingencies....
	Feet.	Cost per Foot.	Cost.	Cost.	Tons of Pipe Coated.	Cost per Ton.	Cost.	Cost.	Cost.	Cost.	Cost.	Cost.	Dollars.	Dollars.
Cook's Reservoir to San Francisco, *via* Carquinez Reservoir	533,280	$ .62	$330,634	$53,328	......	......	......	......	......	......	......	......	......	......
	168,960	.63	106,445	18,586	......	......	......	......	......	......	......	......	......	......
Totals	702,240	......	437,079	71,914	82,486	$6.20	$511,413	$679,320	$50,000	$189,955	$767,406	$33,250	11,747,870	12,922,657
Cook's Reservoir to San Francisco, *via* Carquinez Reservoir	533,280	.62	330,634	53,328	......	......	......	......	......	......	......	......	......	......
	168,960	.56	94,618	15,206	......	......	......	......	......	......	......	......	......	......
Totals	702,240	......	425,252	68,534	76,718	6.20	475,652	679,320	50,000	189,955	767,406	33,250	11,080,205	12,188,226
Cook's Reservoir to San Francisco, *via* Carquinez Reservoir	533,280	.62	330,634	53,328	......	......	......	......	......	......	......	......	......	......
	168,960	.52	87,859	13,516	......	......	......	......	......	......	......	......	......	......
Totals	702,240	......	418,493	66,844	74,849	6.20	464,064	679,320	50,000	189,955	767,406	33,250	10,858,718	11,944,590
Cook's Reservoir to San Francisco, *via* Carquinez Reservoir	533,280	.62	330,634	53,328	......	......	......	......	......	......	......	......	......	......
	168,960	.50	84,480	13,516	......	......	......	......	......	......	......	......	......	......
Totals	702,240	......	415,114	66,844	73,280	6.20	454,336	679,320	50,000	189,955	767,406	33,250	10,678,056	11,745,851
Cook's Reservoir to San Francisco, *via* Shore Line.	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Totals	695,006	.60	417,004	69,501	71,870	6.20	445,594	679,320	50,000	189,955	......	32,907	9,750,619	10,725,681

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AUBURN LINE.—TABLE OF COST OF A CONDUIT FROM DUTCH RAVINE RESERVOIR, (HEIGHT=880 FEET,) DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 20 MILLIONS OF GALLONS PER DAY, THE COST OF TUNNELS UNDER THE BAY OF SAN FRANCISCO AND STRAITS OF CARQUINEZ NOT BEING INCLUDED.

	Length.		Diameter of Pipe in Inches	Height of Delivery above City Base, in Feet....	Iron at $80.00 per ton of 2,000 lbs.		Rivets at $120 per ton of 2,000 lbs.		Shopwork, manufacturing, testing, coating, at $27.50 per ton of Plates	Excavating Trench for Pipe, Joint-holes, Laying Pipes, Ramming, Filling, Etc.						
										Earth.			Rock.			Total Cost of Excavation.
	Miles.	Feet.			Tons.	Cost.	Tons.	Cost.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	
Dutch Ravine Reservoir to San Francisco, *via* Carquinez Reservoir	{ 91.84 { 32.	484,915 168,960	48.28 37.48	....	....	....	....	....	... .	411,417 144,144	$ .67 .48	$275,649 69,189	73,498 24,816	$1.16 .98	$85,257 24,319	....
Totals	123.84	653,875	......	300	73,266	$5,861,280	4,029	$483,480	$2,014,815	555,561	......	344,838	98,314	......	109,576	$454,414
Dutch Ravine Reservoir to San Francisco, *via* Carquinez Reservoir	{ 91.84 { 32.	484,915 168,960	48 28 35.54	....	....	....	....	....	....	411,417 144,144	.67 .44	275,649 63,425	73,498 24,816	1.16 .95	85,257 23,575	....
Totals...............	123.84	653,875	......	200	71,562	5,724,960	3,935	472,200	1,967,955	555,561	......	339,074	98,314	..:..	108,832	447,906
Dutch Ravine Reservoir to San Francisco, *via* Carquinez Reservoir	{ 91.84 { 32.	484,915 168,960	48.28 34.09	....	....	....	....	....	....	411,417 144,144	.67 .41	275,649 59,099	73,498 24,816	1.16 .92	85,257 22,830	....
Totals...............	123.84	653,875	......	100	70,133	5,610,640	3,857	462,840	1,928,657	555,561	......	334,748	98,314	......	108,047	442,835
Dutch Ravine Reservoir to San Francisco, *via* Shore Line	....	....	...... 43.76	....	....	....	....	....	....	405,134 144,144	....	....	72,389 24,816	....	....	....
Totals...............	122 44	646,483	......	300	57,953	4,636,240	3,187	382.440	1,593,707	549,278	.57	312,948	97,205	1.09	105,953	418,901
Dutch Ravine Reservoir to San Francisco, *via* Shore Line	....	....	...... 42.48	....	....	....	....	....	....	....	....	....	....	....	....	....
Totals......	122.44	646,483	......	200	48,772	3,901,760	2,682	321,840	1,341,230	549,278	.56	307,595	97,205	1.08	104,981	412,576

AUBURN LINE.—TABLE OF COST OF A CONDUIT FROM DUTCH RAVINE RESERVOIR, (HEIGHT 880 FEET,) DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 20 MILLIONS OF GALLONS PER DAY, THE COST OF TUNNELS UNDER THE BAY OF SAN FRANCISCO AND STRAITS OF CARQUINEZ NOT BEING INCLUDED—CONCLUDED.

	Mechanical Work on Pipe in the Trench, Riveting, Painting, Handling, etc.			Manholes, Blow-offs, Air-valves, Gates, etc......	Distribution of Pipes including Cartage, loading and unloading, Railroad and Steamer Freights.			Bridges and Piling.	Extra work, crossing the Sacramento river..	Dutch Ravine Reservoir....	Carquinez Reservoir	Telegraph Line at $250.00 per mile.........	Total Cost.	Total cost with 10 per cent. added for contingencies...
	Feet.	Cost per Foot.	Cost.	Cost.	Tons of Pipe Coated.	Cost per Ton.	Cost.	Cost.	Cost.	Cost.	Cost.	Cost.	DOLLARS.	DOLLARS.
Dutch Ravine Reservoir to San Francisco, *via* Carquinez Reservoir	484,915 168,960	$ .73 .56	$353,988 94,617	$67,888 15,206	....	....	....	....	....	....	....	....	....	....
Totals................	653.875	......	448,605	93.094	80,387	$6.20	$498,399	$679,320	$50,000	$124,013	$767,406	$30,960	11,505,786	12,656,365
Dutch Ravine Reservoir to San Francisco, *via* Carquinez Reservoir	484,915 168,960	.73 .52	353,988 87,859	67,888 13,516	....	....	....	....	....	....	....	....	....	....
Totals................	653,875	......	441,847	81,404	78,517	6.20	486,805	679,320	50,000	124,013	767,406	30,960	11,274,776	12,402,253
Dutch Ravine Reservoir to San Francisco, *via* Carquinez Reservoir	484,915 168,960	.73 .50	353,988 84,480	67,888 13,516	....	....	....	....	....	....	....	....	....	....
Totals................	653,875	......	438,468	81,404	70,949	6.20	477,083	679,320	50,000	124,013	767.406	30,960	11,093,626	12,202,989
Dutch Ravine Reservoir to San Francisco, *via* Shore Line....................	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Totals................	646,483	.66	426,679	71,113	62,786	6.20	389,273	679,320	50,000	124,013	....	30,610	8,802,296	9,682,526
Dutch Ravine Reservoir to San Francisco, *via* Shore Line....................	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Totals................	646,483	.65	420,213	64,648	53,512	6.20	331,774	679,320	50,000	124,013	....	30,610	7,677,984	8,445,782

MOKELUMNE LINE.—TABLE OF COST OF A CONDUIT CARRIED OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 32 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF HEAD OF PIPE=1206 FEET. ELEVATION OF LIVERMORE PASS=739 FEET.

	Length.		Diameter of Pipe in Inches.	Height of Delivery above City base in Feet.	Iron at $80.00 per ton of 2000 lbs.		Rivets at $120 per ton of 2000 lbs.		Shopwork, manufacturing, testing and coating, at $27.50 per ton of Plates........	Excavating Trench for Pipe, Joint-holes, Laying Pipe, Ramming, Filling, etc.						
										Earth.			Rock.			Total Cost for Excavation.
	Miles.	Feet.			Tons.	Cost.	Tons.	Cost.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay...	62.83	331,748	48.	....	55,431	....	......	....	....	284,356	$ .67	$190,518	47,392	$1.15	$54,500	....
	74.91	395,523	55.10	....	49,778	....	....	....	....	339,020	.75	254,265	56,503	1.27	71,758	....
Totals...............	137.74	727,271	......	450	105,209	$8,416,720	5,786	$694,320	$2,893,247	623,376	......	444,783	103,895	......	126,258	$571,041
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay....	62.83	331,748	48.	....	55,431	....	......	....	....	284,356	.67	190,518	47,392	1.15	54,500	....
	74.91	395,523	50.34	....	35,247	....	......	....	....	339,020	.69	233,923	56,503	1.19	67,238	....
Totals...............	137.74	727,271	......	300	90,678	7,254,240	4,987	598,440	2.493,645	623,376	......	424,441	103,895	......	121,738	546,179
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay ...	62.83	331,748	48.	....	55,431	....	......	....	....	284,356	.67	190,518	47,392	1.15	54,500	....
	74.91	395,523	48.47	....	29,018	....	......	....	....	339,020	.67	227,143	56,503	1.16	65,543	....
Totals...............	137.74	727,271	......	200	84,449	6,755,920	4,641	556,920	2,322,348	623,376	......	417,661	$103,895	......	120,043	537,704
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay...	62.83	331,748	48.	....	55,431	....	......	....	....	284,356	.67	190,518	47,392	1.15	54,500	....
	74.91	395,523	46.89	....	23,738	......	......	....	....	339,020	.61	206,802	56,503	1.13	63,848	....
Totals	137.74	727,271	......	100	79,169	6,333,520	4,354	522,480	2,177,147	623,376	......	397,320	103,895	......	118,348	515,668

MOKELUMNE LINE.—TABLE OF COST OF A CONDUIT CARRIED OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 32 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF HEAD OF PIPE = 1206 FEET. ELEVATION OF LIVERMORE PASS = 739 FEET – CONTINUED.

	Mechanical Work on Pipe in the Trench, Riveting, Painting, Handling, etc.			Manholes, Blow-offs, Air-valves, Gates, etc........	Distribution of Pipes including Cartage, loading and unloading, Railroad and Steamer freights.			Bridges and Piling.	Extra work crossing the San Joaquin River....	Livermore Reservoir...	Butte Valley Reservoir.	Telegraph Line at $250 per mile..........	Total Cost.	Total Cost with 10 per cent. added for Contingencies..........
	Feet.	Cost per Foot.	Cost.	Cost.	Tons of Pipe Coated.	Cost per Ton.	Cost.	Cost.	Cost.	Cost.	Cost.	Cost.	Dollars.	Dollars.
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay ...	331,748 395,523	$ .73 .85	$242,176 336,194	$46,444 63,283	....	....	....	....	....	....	....	....	....	....
Totals	727,271	......	578,370	109,727	115,434	$6 00	$692,604	$341,625	$20,000	$60,680	$231,294	$34,435	14,643,368	16,107,705
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay ...	331,748 395,523	.73 .76	242,176 300,597	46,444 59,328	....	....	....	....	....	....	....	....	....	....
Totals...............	727,271	......	542,773	105,772	99,491	6.00	596,946	341,625	20,000	60,680	231,294	34,435	12,826,029	14,108,632
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay....	331,748 395,523	.73 .74	242,176 292,687	46,444 55,373	....	....	....	....	....	....	....	....	....	....
Totals...............	727,271	......	534,863	101,817	92,653	6 00	555,918	341,625	20,000	60,680	231,294	34,435	12,053,524	13,258,876
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Head of Bay...	331,748 395,523	.73 .71	242,176 280,821	46,444 47,462	....	....	....	....	....	....	....	....	....	....
Totals...............	727,271	......	522,997	93,906	86,864	6 00	521,184	341,625	20,000	60,680	231,294	34,435	11,385,347	12,523,882

MOKELUMNE LINE.—TABLE OF COST OF A CONDUIT CARRIED OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 32 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF HEAD OF PIPE = 1206 FEET. ELEVATION OF LIVERMORE PASS = 739 FEET—CONTINUED.

	LENGTH.		Diameter of Pipe in Inches.	Height of delivery above City base, in Feet	IRON AT $80.00 PER TON OF 2000 lbs.		RIVETS AT $120 PER TON OF 2000 lbs.		Shopwork, manufacturing, testing and coating, at $27.50 per ton of Plates	EXCAVATING TRENCH FOR PIPE, JOINT-HOLES, LAYING PIPE, RAMMING, FILLING, ETC.						
										EARTH.			ROCK.			Total Cost for Excavation.
	Miles.	Feet.			Tons.	Cost.	Tons.	Cost.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	62.83	331,748	48.	....	55,431	....	......	....	....	284,356	$ .67	$190,518	47,392	$1.15	$54,500	....
	64.	337,920	53.38	....	37,618	....	......	....	....	289,646	.73	211,441	48,274	1.25	60,342	....
Totals	126.83	669,668	......	450	93,049	$7,443,920	5,118	$614,160	$2,558,847	574,002	......	401,959	95,666	......	114,842	$516,801
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	62.83	331,748	48.	....	55,431	....	......	....	....	284,356	.67	190,518	47,392	1.15	54,500	....
	64.	337,920	48.98	....	26,337	....	......	....	....	289,646	.68	196,957	48,274	1.16	55,997	....
Totals................	126.83	669,668	......	300	81,768	6,541,440	4,497	539,640	2,248,620	574,002	......	387,475	95,666	.....	110,497	497,972
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	62.83	331,748	48.	....	55,431	....	......	....	....	284,356	.67	190,518	47,392	1.15	54,500	....
	64.	337,920	46.96	....	21,179	....	......	....	....	289,646	.61	176,684	48,274	1.13	54,549	....
Totals................	126.83	669,668	......	200	76,610	6,128,800	4,214	505,680	2,106,775	574,002	......	367,202	95,666	......	109,049	476,251
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	62.83	331,748	48.	...	55,431	....	......	....	....	284,356	.67	190,518	47,392	1.15	54,500	....
	64.	337,920	45.37	....	17,659	....	......	....	....	289,646	.60	173,787	48,274	1.11	53,584	....
Totals...............	126.83	669,668	......	100	73,090	5,847,200	4,120	494,400	2,009,974	574,002	.....	364,305	95,666	......	108,084	472,389

MOKELUMNE LINE.—TABLE OF COST OF A CONDUIT CARRIED OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 32 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF HEAD OF PIPE =1206 FEET. ELEVATION OF LIVERMORE PASS=739 FEET—CONCLUDED.

	Mechanical Work on Pipe in the Trench, Riveting, Painting, Handling, etc.			Manholes, Blow-offs, Air-valves, Gates, etc.	Distribution of Pipes including Cartage, Loading and Unloading, Railroad and Steamer Freights.			Bridges and Piling.	Extra work crossing the San Joaquin River	Livermore Reservoir	Butte Valley Reservoir.	Telegraph Line at $250 per mile	Total Cost.	Total Cost with 10 per cent. added for Contingencies
	Feet.	Cost per Foot.	Cost.	Cost.	Tons of Pipe Coated.	Cost per Ton.	Cost.	Cost.	Cost.	Cost.	Cost	Cost.	Dollars.	Dollars.
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	331,748	$ .73	$242,176	$46,444	....	......	....	....	....	....	....	....	....	....
	337,920	.82	277,094	50,688	....	......	....	....	....	....	....	....	....	....
Totals..........	669,668	......	519,270	97,132	102,093	$6 00	$612,558	$380,495	$20,000	$60,680	$231,294	$31,708	13,086,865	14,395,551
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	331,748	.73	242,176	46,444	....	......	....	....	....	....	....	....	....	....
	337,920	.74	250,060	47,308	....	......	....	....	....	....	....	....	....	....
Totals..........	669,668	......	492,236	93,752	89,715	6 00	538,290	380,495	20,000	60,680	231,294	31,708	11,676,137	12,843,751
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	331,748	.73	242,176	46,444	....	......	....	....	....	....	....	....	....	....
	337,920	.70	236,544	40,550	....	......	....	....	....	....	....	....	....	....
Totals..........	669,668	......	478,720	86,994	84,057	6 00	504,342	380,495	20,000	60,680	231,294	31,708	11,012,739	12,114,013
Blue Lakes Line from beginning of Pipe to San Francisco, *via* Ravenswood....	331,748	.73	242,176	46,444	....	......	....	....	....	....	....	....	....	....
	337,920	.68	229,785	40,550	....	......	....	....	....	....	....	....	....	....
Totals..........	669,668	......	471,961	86,994	80,193	6 00	481,158	380,495	20,000	60,680	231,294	31,708	10,588,253	11,647,078

LINE FROM THE SOUTH FORK OF THE AMERICAN RIVER.—TABLE OF COST OF A CONDUIT FROM BORLAND'S RESERVOIR OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 32 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF BORLAND'S RESERVOIR=1325 FEET. ELEVATION OF LIVERMORE PASS=739 FEET.

	Length.		Diameter of Pipe in Inches.	Height of Delivery above City Base, in Feet........	Iron at $80.00 per ton of 2000 lbs.		Rivets at $120 per ton of 2000 lbs.		Shopwork, manufacturing, testing and coating, at $27.50 per ton of Plates............	Excavating Trench for Pipe, Joint-holes, Laying Pipe, Ramming, Filling, etc.						
										Earth.			Rock.			Total Cost for Excavation.
	Miles.	Feet.			Tons.	Cost.	Tons.	Cost.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	
Borland's Reservoir to San	82.36	434,860	48.39	....	74,293	....	......	....	....	377,534	$ .67	$252,947	57,326	$1.15	$65,925	....
Francisco, *via* Head of Bay.	74.91	395,524	55.10	....	49,778	....	......	....	....	347,251	.75	260,439	48,274	1.27	61,307	....
Totals.........	157.27	830,385	.....	450	124,071	$9,925,680	6,824	$818,880	$ 3,411,952	724,785	......	513,385	105,600	......	127,232	$640,617
Borland's Reservoir to San	82.36	834,860	48.39	....	74,293	....	......	....	....	377,534	.67	252,947	57,326	1.15	65,925	....
Francisco, *via* Head of Bay.	74.91	395,524	50.34	....	35,247	....	......	....	....	347,251	.69	239,603	48,274	1.19	57,446	....
Totals.....	157.27	830,385	.....	300	109,540	8,763,200	6,025	723,000	3,012,350	724,785	......	492,550	105,600	......	123,371	615,921
Borland's Reservoir to San	82.36	434,860	48.39	....	74,293	....	......	....	....	377,534	.67	252,947	57,326	1.15	65,925	....
Francisco, *via* Head of Bay.	74.91	395,524	48.47	....	29,018	....	.. ...	... .	....	347,251	.67	232,658	48,274	1.16	55,997	....
Totals......	157.27	830,385	.....	200	103,311	8,264,880	5,682	681,840	2,841,052	724,785	......	485,605	105,600	......	121,922	607,527
Borland's Reservoir to San	82.36	434,860	48.39	....	74,293	....	......	....	....	377,534	.67	252,947	57,326	1.15	65,925	....
Francisco, *via* Head of Bay.	74.91	395,524	46.89	....	23,738	....	......	....	....	347,251	.61	211,823	48,274	1.13	54,549	....
Totals	157.27	830,385	.....	100	98,037	7,842,960	5,392	647,040	2,696,017	724,785	... ..	464,770	105,600	......	120,474	585,244

LINE FROM THE SOUTH FORK OF THE AMERICAN RIVER.—TABLE OF COST OF A CONDUIT FROM BORLAND'S RESERVOIR OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 32 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF BORLAND'S RESERVOIR=1325 FEET. ELEVATION OF LIVERMORE PASS=739 FEET.—CONTINUED.

	Mechanical Work on Pipe in the Trench, Riveting, Painting, Handling, etc.			Manholes, Blow-offs, Air-valves, Gates, etc.	Distribution of Pipes including Cartage, Loading and Unloading, Railroad and Steamer Freights.			Bridges and Piling.	Extra work crossing the San Joaquin River	Livermore Reservoir	Borland's Reservoir	Telegraph Line at $250 per mile	Total Cost.	Total Cost with 10 per cent. added for Contingencies
	Feet.	Cost per Foot.	Cost.	Cost.	Tons of Pipe Coated.	Cost per Ton.	Cost.	Cost.	Cost.	Cost.	Cost.	Cost.	Dollars.	Dollars.
Borland's Reservoir to San Francisco, *via* Head of Bay.	434,860 395,524	$ .73 .85	$317,447 336,195	$60,880 63,283										
Totals	830,885		653,642	124,163	136,131	$5 85	$796,366	$456,907	$20,000	$60,680	$319,867	$39,317	17,268,131	18,994,944
Borland's Reservoir to San Francisco, *via* Head of Bay.	434,860 395,524	.73 .76	317,447 300,598	60,880 59,328										
Totals	830,885		618,045	120,208	120,188	5 85	703,099	456,907	20,000	60,680	319,867	39,317	15,452,594	16,997,853
Borland's Reservoir to San Francisco, *via* Head of Bay.	434,860 395,524	.73 .73	317,447 288,732	60,880 55,373										
Totals	830,885		606,179	116,253	113,353	5 85	663,115	456,907	20,000	60,680	319,867	39,317	14,677,617	16,145,378
Borland's Reservoir to San Francisco, *via* Head of Bay.	434,860 395,524	.73 .70	317,447 276,866	60,880 51,418										
Totals	830,885		594,313	112,298	107,566	5 85	629,261	456,907	20,000	60,680	319,867	39,317	14,003,904	15,404,294

LINE FROM THE SOUTH FORK OF THE AMERICAN RIVER.—TABLE OF COST OF A CONDUIT FROM BORLAND'S RESERVOIR OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 32 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF BORLAND'S RESERVOIR=1325 FEET. ELEVATION OF LIVERMORE PASS 739 FEET.—CONTINUED.

	Length.		Diameter of Pipe in Inches.	Height of Delivery above City Base, in Feet........	Iron at $80.00 per ton of 2000 lbs.		Rivets at $120 per ton of 2000 lbs.		Shopwork, manufacturing, testing and coating, at $27.50 per ton of Plates....	Excavating Trench for Pipe, Joint-holes, Laying Pipe, Ramming, Filling, etc.						
										Earth.			Rock.			Total Cost for Excavation.
	Miles.	Feet.			Tons.	Cost.	Tons.	Cost.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	
Borland's Reservoir to San Francisco, *via* Ravenswood	82.36 64.	434,860 337,920	48.39 53.38	....	74,293 37,618	....	....	....	....	377,534 289,646	$ .67 .73	$252,947 211,441	57,326 48,274	$1.15 1.25	$65,925 60,342	....
Totals...............	146.36	772,780	.....	450	111,911	$8,952,880	6,155	$738,600	$3,077,552	667,180	......	464,388	105,600	......	126,267	$590,655
Borland's Reservoir to San Francisco, *via* Ravenswood	82.36 64.	434,860 337,920	48.39 48.98	....	74,293 26,337	....	....	....	....	377,534 289,646	.67 .68	252,947 196,959	57,326 48,274	1.15 1.16	65,925 55,997	....
Totals...............	146.36	772,780	.....	300	100,630	8,050,400	5,534	664,080	2,767,325	667,180	......	449,906	105,600	......	121,922	571,828
Borland's Reservoir to San Francisco, *via* Ravenswood	82.36 64.	434,860 337,920	48.39 46.96	....	74,293 21,179	....	....	....	....	377,534 289,646	.67 .61	252,947 176,684	57,326 48,274	1.15 1.13	65,925 54,549	....
Totals...............	146.36	772,780	.....	200	95,472	7,637,760	5,251	630,120	2,625,480	667,180	.....	429,631	105,600	......	120,474	550,105
Borland's Reservoir to San Francisco, *via* Ravenswood	82.36 64.	434,860 337,920	48.39 45.37	....	74,293 17,659	....	....	....	....	377,534 289,646	.67 .60	252,947 173,787	57,326 48,274	1.15 1.11	65,925 53,584	.. ..
Totals...............	146.36	772,780	.....	100	91,951	7,356,080	5,057	606,840	2,528,652	667,180	......	426,734	105,600	......	119,509	546,243

LINE FROM THE SOUTH FORK OF THE AMERICAN RIVER.—TABLE OF COST OF A CONDUIT FROM BORLAND'S RESERVOIR OVER LIVERMORE PASS, DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO, 32 MILLIONS OF GALLONS PER DAY, THE COST OF A TUNNEL UNDER THE BAY OF SAN FRANCISCO NOT BEING INCLUDED. ELEVATION OF BORLAND'S RESERVOIR=1325 FEET. ELEVATION OF LIVERMORE PASS=739 FEET.—CONCLUDED.

	Mechanical Work on Pipe in the Trench, Riveting, Painting, Handling, etc.			Manholes, Blow-offs, Air-valves, Gates, etc.	Distribution of Pipes including Cartage, Loading and Unloading, Railroad and Steamer Freights.			Bridges and Piling.	Extra work crossing the San Joaquin River	Livermore Reservoir	Borland's Reservoir	Telegraph Line at $250 per mile	Total Cost.	Total Cost with 10 per cent. added for Contingencies
	Feet.	Cost per Foot.	Cost.	Cost.	Tons of Pipe Coated.	Cost per Ton.	Cost.	Cost.	Cost.	Cost.	Cost.	Cost.	Dollars.	Dollars.
Borland's Reservoir to San Francisco, *via* Ravenswood.	434,860 337,920	$ .73 .81	$317,447 273,715	$60,880 50,688	......	......	......	......	......	......	......	......	......	......
Totals	772,780	......	591,162	111.568	122,789	$5.85	$718,409	$456,907	$20,000	$60,680	$319, 8 6	$36,590	15,674,870	17,242,357
Borland's Reservoir to San Francisco, *via* Ravenswood.	434,860 337,920	.73 .75	317,447 253,440	60,880 47,308	......	......	......	......	......	......	......	......	......	......
Totals	772,780	......	570,887	108,188	110,410	5.85	645,898	456,907	20,000	60,680	319,867	36,590	14,272,650	15,699,915
Borland's Reservoir to San Francisco, *via* Ravenswood.	434,860 337,920	.73 .71	317,447 239,923	60,880 43,927	......	......	......	......	......	......	......	......	......	......
Totals	772,780	......	557,370	104,809	104,752	5.86	612,799	456,907	20,000	60,680	319,867	36,590	13,612,487	14,973,736
Borland's Reservoir to San Francisco, *via* Ravenswood.	434,860 337,920	.73 .68	317,447 229,785	60,880 40,550	......	......	......	......	......	......	......	......	......	......
Totals	772,730	......	547,232	101,430	100,888	5.85	590,195	456,907	20,000	60,680	319,867	36,590	13,170,716	14,487,788

AUBURN LINE.—TABLE OF COST OF A CONDUIT DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 32 MILLIONS OF GALLONS PER DAY, BY VARIOUS ROUTES THROUGH OAKLAND, FROM COOK'S RESERVOIR, (HEIGHT 1326 FEET,) THE COST OF TUNNELS UNDER THE BAY OF SAN FRANCISCO, AND STRAITS OF CARQUINEZ NOT BEING INCLUDED.

	Length.		Diameter of Pipe in Inches	Height of deliv'ry above City Base, in Feet..........	Iron at $80.00 per ton of 2,000 lbs.		Rivets at $120 per ton of 2,000 lbs.		Shopwork, manufacturing, testing, coating, at $27.50 per ton of Plates..........	Excavating Trench for Pipe, Joint-holes, Laying Pipes, Ramming, Filling, Etc.						
										Earth.			Rock.			Total Cost of Excavation.
	Miles.	Feet.			Tons.	Cost.	Tons.	Cost.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	Lineal Feet.	Cost per Foot.	Cost.	
Cook's Reservoir to San Francisco, *via* Carquinez	101.00	533,280	48.64	......	88,116	....	......	....	....	452,496	$ .67	$303,172	80,784	$1.16	$93,709	... .
Reservoir	32.00	168,960	51.43	......	20,051	....	......	....	....	144,144	.70	100,900	24,816	1.20	29,779	....
Totals................	133.00	702,240	......	450	108167	$8,653,360	5,949	$713,880	$2,974,592	596,640	......	404,072	105,600	......	123,480	$527,560
Cook's Reservoir to San Francisco, *via* Carquinez	101.00	533,280	48.64	......	88,116	....	......	....	....	452,496	.67	303,172	80,784	1.16	93,709	....
Reservoir	32.00	168,960	44.98	......	12,836	....	......	....	....	144,144	.60	86,486	24,816	1.10	27,297	....
Totals................	133.00	702,240	......	300	100952	8,076,160	5,552	666,240	2,776,180	596,640	......	389,658	105,600	......	121,006	510,664
Cook's Reservoir to San Francisco, *via* Carquinez	101.00	533,280	48.64	......	88,116	....	......	....	....	452,496	.67	303,172	80,784	1.16	93,709	....
Reservoir.................	32.00	168,960	42.63	......	10,524	....	......	....	....	144,144	.56	80,720	24,816	1.08	26,801	....
Totals................	133.00	702,240	......	200	98,640	7,891,200	5,425	651,000	2,712,600	596,640	......	383,892	105,600	......	120,510	504,402
Cook's Reservoir to San Francisco, *via* Carquinez	101.00	533,280	48.64	......	88,116	....	......	....	....	452,496	.67	303,172	80,784	1.16	93,709	....
Reservoir.........	32.00	168,960	40.89	......	8,313	....	......	....	....	144,144	.52	74,954	24,816	1.04	25,808	....
Totals................	133.00	702,240	......	100	96,429	7,714,320	4,985	598,200	2.651,797	596,640	......	378,126	105,600	......	119,517	497,643
Cook's Reservoir to San	101.00	533,280														
Francisco, *via* Shore Line.	30.63	161,726	......	......	......	....	......	....	....	....	......	....	....	......	....	....
Totals................	131.63	695,006	47.58	300	97,040	7,763,200	5,337	640,440	2,668,600	589,406	.66	389,007	105,600	1.15	121,440	510,447

AUBURN LINE.—TABLE OF COST OF A CONDUIT DELIVERING AT DIFFERENT HEIGHTS IN SAN FRANCISCO 32 MILLIONS OF GALLONS PER DAY, BY VARIOUS ROUTES THROUGH OAKLAND, FROM COOK'S RESERVOIR, (HEIGHT=1326 FEET,) THE COST OF TUNNELS UNDER THE BAY OF SAN FRANCISCO AND STRAITS OF CARQUINEZ NOT BEING INCLUDED.—CONCLUDED.

	Mechanical Work on Pipe in the Trench, Riveting, Painting, Handling, etc.			Manholes, Blow-offs, Air-valves, Gates, etc......	Distribution of Pipes including Cartage, Loading and Unloading, Railroad and Steamer Freights.			Bridges and Piling.	Extra work crossing the Sacramento River....	Cook's Reservoir	Carquinez Reservoir.	Telegraph Line at $250.00 per mile...	Total Cost.	Total Cost with 10 per cent. added for Contingencies ....
	Feet.	Cost per Foot.	Cost	Cost	Tons of Pipe Coated.	Cost per Ton.	Cost.	Cost.	Cost.	Cost.	Cost.	Cost.	Dollars.	Dollars.
Cook's Reservoir to San Francisco, *via* Carquinez Reservoir........	533,280	$ .73	$389,294	$74,659	....	......	....	....	....	....	....	....	....	....
	168,960	.77	130,099	25,344	....	......	....	....	....	....	....	....	....	....
Totals................	702,240	......	519,393	100,003	118,680	$6 20	$735,816	$679,320	$50,000	$189,955	$767,406	$33,250	15,944,535	17,538,989
Cook's Reservoir to San Francisco, *via* Carquinez Reservoir................	533,280	.73	389,294	74,659	....	......	....	....	....	....	....	....	....	....
	168,960	.67	113,203	20,275	....	......	....	....	....	....	....	....	....	....
Totals................	702,240	......	502,497	94,934	110,764	6 20	686,736	679,320	50,000	189,955	767,406	33,250	15,033,342	16,536,676
Cook's Reservoir to San Francisco, *via* Carquinez Reservoir................	533,280	.73	389,294	74,659	....	......	....	....	....	....	....	....	....	....
	168,960	.65	109,824	18,585	....	......	....	....	....	....	....	....	....	....
Totals................	702,240	......	499,118	93,244	108,228	6 20	671,013	679,320	50,000	189,955	767,406	33,250	14,742,508	16,216,758
Cook's Reservoir to San Francisco, *via* Carquinez Reservoir................	533,280	.73	389,294	74,659	....	......	....	....	....	....	....	....	....	....
	168,960	.63	106,444	16,896	....	......	....	....	....	....	....	....	....	....
Totals................	702,240	......	495,788	91,555	105,471	6 20	653,920	679,320	50,000	189,955	767,406	33,250	14,423,101	15,865,414
Cook's Reservoir to San Francisco, *via* Shore Line.	....	......	....	....	....	......	....	....	....	....	....	....	....	....
	....	......	....	....	....	......	....	....	....	....	....	....	....	....
Totals...............	695,006	.72	500,404	97,300	106,472	6 20	660,126	679,320	50,000	189,955	....	32,907	13,792,699	15,171,969

GENERAL REMARKS ON THE GRAVITATION LINES FROM THE SIERRA NEVADA.

It may be well at this stage of study, at the risk of some repetition, to gather in compact form the main facts and features of the Sierra lines.

The MOKELUMNE LINE, with the original line of canal and by way of the head of the Bay, is 189.5 miles, of which 51¾ are of canal and 137¾ of iron conduit. The examination made by Mr. Allardt shows that a better canal may be made, not to exceed 38 miles in length. Adopting this conclusion, the total length of aqueduct is 175¾ miles.

The LINE from the SOUTH FORK OF THE AMERICAN is 202¼ miles, 45 miles being of canal and 157¼ of iron conduit.

The LAKE TAHOE LINE has 75 miles of canal and 133 miles of conduit, in all 208 miles. In addition it has a tunnel through the Sierra Nevada 4⅝ miles, and others under the Straits of Carquinez and the Bay of San Francisco 5½ miles, making a total of quite 10 miles.

By using the lower reservoir at Dutch Ravine, the iron conduit line from Lake Tahoe is 123.8 miles, the canal being however lengthened to correspond.

The iron conduit line from Lake Tahoe is the same as it would be from the North Fork of the American.

The lengths of these lines, and the pressures which are sustained by the lower portions of the syphons, are features of unusual dimensions, and they give a character to these enterprises which is peculiar to themselves.

No city in the world goes such a distance for water. Paris perhaps approaches it most nearly for a part of its supply. London has had under consideration projects of supply from North Wales and from the Cumberland Lakes, involving conduits of 180 and 270 miles respectively. She continues however to draw her main supply from the Thames, at no great distance. All of the American cities as yet obtain supplies without going to great distances. New York has a conduit 40 miles in length, and this is believed to be the longest yet built in America.

So far as practicability in an engineering point of view is concerned, for lines all on land there seems to be no reason to entertain doubts. The scale of the works surpasses any similar construction yet made, but there appears to be nothing in the scale of the operations, which throws any doubt upon the application of principles which have proved successful in minor examples.

We have no pipes of 48 inches diameter under a pressure of 900 or 1,000 feet of water, but we have a 30-inch pipe under 860 feet. We have smaller pipes under as much as 1,700 feet pressure.

The character and magnitude of the strains to be borne are known and subject to exact calculation. We may determine with confidence the thickness of iron of given strength which will resist this strain. We provide that no shocks shall impair the strength of the material, which we protect as well as may be from rust by a bituminous coating.

Breaches in the iron conduit will be due mainly to a disturbance of the foundation of the pipe, such as undermining by extraneous water, movements in bad ground, or leakages in the pipe. The breaches will therefore be infrequent, provided a proper care is exercised in constructing and placing the pipe. Nevertheless, it will be recognized that the chances of accident are in a measure proportioned to the length of the line, and a short line is unquestionably safer than a long one. The seriousness of an accident when it occurs is proportioned to the pressure.

The conditions which exist on the canal part of the line are different and more unfavorable, so far as interruptions are concerned.

It has been explained that the first few miles of the canals, after they leave the river beds, are on the flanks of steep, timbered mountains, which rise at first a couple of thousand feet high. After a few miles, the canals emerge from these cañons, and as a rule occupy better and safer ground.

In the winter the upper part of the line is exposed to damage by breaches, due to sliding earth or snow. With all the precautions which it will be possible to take, either in location or construction, it cannot be expected that breaches can be prevented. This fact requires that the canal shall be under constant observation. It will be essential to have patrolmen, with distances of eight or ten miles or less under their care. These men will be able to repair slight damages, and in some cases prevent serious embarrassment by timely attention.

The arrangement of reservoirs, however, assures that the city supply shall not be interrupted by temporary breaches of the canals.

When the consumption of the city shall require further supply, a second conduit may be laid.

The canals are proportioned for 100 millions of gallons daily, and it will not be necessary to provide new canals until the iron conduits require 100 millions of gallons.

The canals having a fall not less than six feet per mile, the velocity will be about three miles an hour.

The temperature of the water will be well preserved.

The mean velocity of the water in the pipes will vary in different cases, on either side of four feet a second, which may be taken as an average.

The conduit line will require a police force to patrol it, a man to every ten or twelve miles. With communication between these men by telegraph, it would be possible to concentrate several at any point, where their attention was specially required. A keeper will be required at each of the reservoirs, including those in the mountains. Foremen will be required to oversee such divisions as it may be expedient to create. Perhaps three divisions would be required—one for the canal, and two for the iron conduit lines. The foremen would receive instructions from a superintendent of the whole line.

It will be apparent that the expense of police and maintenance will bear a pretty close relation to the length of the line. The expense of the city office and its administration will be about the same for all lines.

THE SAN JOAQUIN RIVER.

The San Joaquin, after it has received its lower tributaries, is next to the Sacramento the largest river in the State of California. In the lower half of its length it flows to the north and unites with the Sacramento in a common delta. Its main basin, whether regarded as to area or to the quantity of drainage, lies to the east of the river and includes the western flanks of the Sierra. The length of this area measured along the crest of the Sierra Nevada is in excess of one hundred miles, and the breadth of the mountain from the plains to the summit is fully sixty miles, so that the area of mountains which contribute to the flow of the river from the east is quite six thousand square miles. Its principal tributaries are the Merced, the Tuolumne and the Stanislaus rivers.

The general characteristics as to topographical features, geological structure and timber, are similar to those which have already been described as belonging to the Mokelumne and the American rivers. The granite is however more prominent and less mingled with basaltic rocks than in the more northerly districts. Within this drainage basin are found the highest peaks of the Sierra.

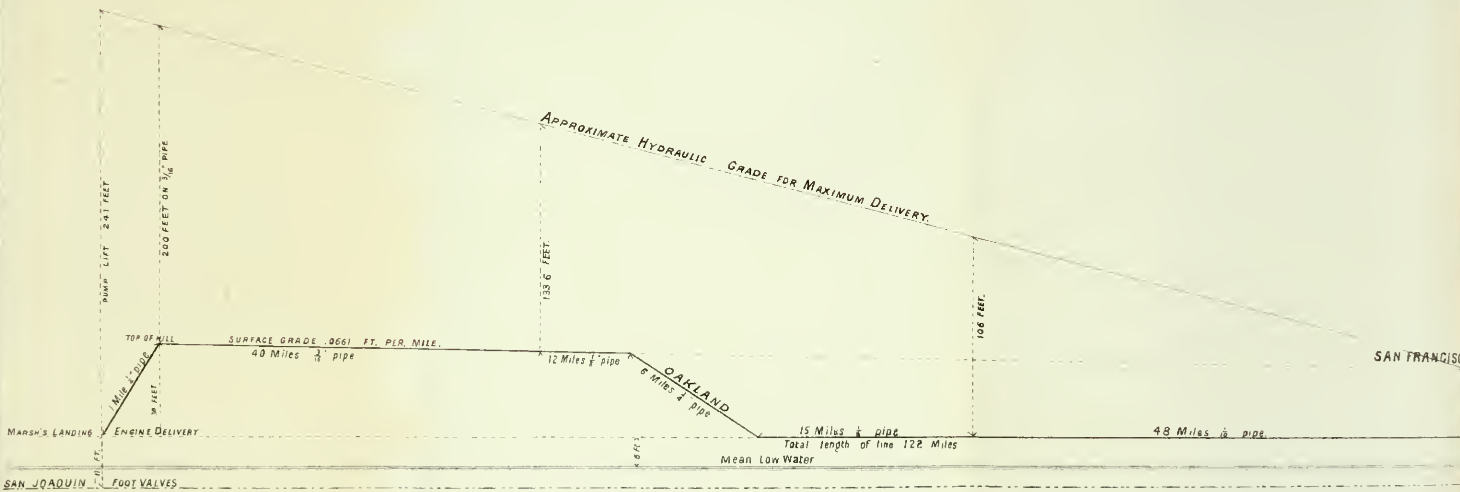
The meteorological conditions, except as varied by the greater height of the mountains, are probably identical with those already described.

In seasons of high freshets the overflow of Tulare Lake, which receives the drainage of King's and Kern rivers, escapes by Fresno Slough into the San Joaquin, but ordinarily the capacity of Tulare Lake is sufficient to retain its own drainage water. The river is subject to the changes of volume, which are common to the streams coming from the Sierra Nevada. It has as a rule two high water stages in the course of the year—one in December or January, due to the rainfall on the lower part of its basin, and the other in May or June, which is caused by the melting of the snow in the higher regions of the Sierra. After this summer maximum the river steadily declines in volume until about November, when it again begins to rise. The quantity of water in the river in its higher or even in its ordinary stages is many times in excess of any city requirements. We are, however, without any accurate knowledge of its flow in the low stages.

We have seen the drainage of the Mokelumne reduced to 50,000 gallons a day from a square mile of area. Applying the same rule to the San Joaquin, its lowest flow may be expected to be something like 300 millions of gallons daily. The influence of the high belt of mountains comprising Mts. Whitney, Lyell and others, within the district which is the highest in the Sierra, would naturally tend to give a larger flow in the low stage than belongs to the rivers to the north, which do not drain such high levels. However this may be, there seems to be no reasonable cause for doubt or apprehension as to the river supply, without the aid of storage reservoirs.

For about one hundred miles measured in a right line above the junction with the Sacramento, the San Joaquin flows through a plain bordered for a part

PROFILE of line of Conduit of the SAN JOAQUIN & SAN FRANCISCO WATER WORKS Co.



of its course by overflowed lands which support a growth of tule, while on either side the fertile lands of the valley rise with a gentle slope of eight or ten feet to the mile to the foothills of the Sierra on one side and to the Mt. Diablo range on the other. These lands are all under private ownership, and are used either in the cultivation of cereals or for grazing purposes. The rainfall in the plains is, however, as a rule smaller than in other valleys of the State, and this is particularly true of the west side. The small rainfall makes the cultivation of crops very uncertain, and has led to the introduction of irrigation. This system of cultivation is as yet in its infancy, but we may expect it to grow with tolerable regularity until the whole of the eastern plains between the foothills and the river shall be irrigated. Investigation has shown that the mountains supply an abundance of water for this purpose, more than will probably ever be applied.

The situation on the west side is less favorable. The Mt. Diablo range is both lower and drier than the Sierra. Little or no precipitation occurs in the form of snow. The drainage from these hills is therefore rapid, and for the greater part of every year there is no water in the river beds. The San Joaquin and Tulare Lake must supply the water which is to irrigate this side of the valley. The absence of streams on the west side requires a larger and more expensive system of canals than will be necessary for the east side. It is, however, to be expected that this side of the valley will within a few years be extensively irrigated.

A certain but not large amount of mining is done on the Tuolumne and Stanislaus rivers, and the detritus enters the rivers and discolors them to a certain degree.

The lower part of the river is affected by the tides, which produce about the same changes of level as are observed in San Francisco Bay. These changes of level extend as high or higher than the points where it is proposed to divert the water for the city use. This action shows itself at these points, however, merely in the rise and fall. The water is so far as is known always fresh. The highest points to which the salt water extends in these rivers, and the variations in this respect if any which occur in seasons of maximum and minimum rainfall, have never received full investigation; but we have no reason to believe that the water at the point of diversion is ever salt or brackish.

The quantity and quality of water, as they may be affected by a complete system of irrigation—by the growth of tule on the banks—by the presence of a considerable agricultural population in the valley, with its proportion of towns and villages—and by mining—are questions of importance which cannot be passed unnoticed.

The Commissioners visited the proposed point of appropriation on Old River, in March of the present year, and in so doing they passed in daylight up the river from Antioch. At the latter point the water was very much discolored, and the appearance of the river might perhaps be called tawny. In ascending the river this appearance underwent a perceptible change for the

better, and at the proposed headworks the color had almost entirely disappeared. There was, however, a slight whitishness or turbidity at this point, which hardly perceptible by itself, became quite noticeable when compared with perfectly clear water. This appearance is noticed in the analysis by Professor Price, which will be referred to hereafter. This turbidity is the measure of the effect of the mining operations, and if the occasion of the visit by the Commissioners can be regarded as a test on this point, the objection can hardly be regarded as serious. In the Old River the action of the tides in alternating the direction of the current, turning it up and then down, and in varying the velocity, has doubtless the effect of causing a deposition of a large part of the detritus, which under other circumstances would be held in suspension. If any objection can be founded on the presence of mining it can be met by a storage in reservoirs or by a simple system of filtering, which will at the same time remove any floating vegetable matter in the water which may result from the presence of tule.

The questions which concern the irrigation and the presence of a large population in the valley are of more importance.

The effect of the abstraction of large volumes of water from the rivers—for the purposes of irrigating adjoining lands—on the flow at points a few miles below the diverson, is discussed at some length in the report of the United States Commissioners of Irrigation, published in 1874. The experience in Italy and India, as observed and discussed by their ablest engineers, seems to dispose of this portion of the subject in a thorough manner, by proving that the water is returned to the rivers in so large proportion that the quantity a few miles below appears to be undiminished, either absolutely or only in small degree.

This conclusion is somewhat at variance with preconceived notions, but there can be no doubt of its soundness. Indeed we have a very apt illustration of its truth in the water production of Lake Merced, which is elsewhere discussed in this report. This Lake receives its water under conditions almost identical with those which will apply to the San Joaquin when the adjoining lands shall be irrigated. The rainfall on the Lake Merced basin percolates through a sandy soil until it reaches the underlying impermeable stratum, along which it trickles protected from evaporation until it reaches the Lake. The plain on the east side of the San Joaquin is underlaid by a similar stratum, which gives reason to hope that the water supply in the main river will actually be increased in the low stages by a systematic irrigation, which will use the water in its season of abundance and restore the greater part to the river by degrees later in the season.

The question of the quality of water as affected by drainage and sewage from highly populated and cultivated districts, has been the subject of much discussion. This point has at present little importance, inasmuch as the San Joaquin Valley is very sparsely inhabited, but we may expect to see a large population here at some future day.

An elaborate inquiry was made by a Parliamentary Commission within the

last seven or eight years in reference to the Thames, from which the greater part of the supply of London is derived. The points of appropriation are above the city, but within a few miles of it. The drainage basin above the point of appropriation contains several large towns, such as Oxford, Aylesbury and Reading, each containing over 25,000 people, the sewage of which was until recently discharged into the river. The arable land was and is habitually manured, and its drainage necessarily goes to the river. The total area above the point of diversion of the water is 3,675 square miles, and the population numbers about one million. The unfavorable influences which these causes have exerted on the water of the river have been borne by the large population of London for generations, without any well established epidemics or general unhealthiness of the inhabitants traceable to the impurity of the water.

This broad statement of the facts affecting a population of 3,000,000, existing through a series of years, is sufficient at least to create the presumption that whatever noxious influences may be exerted by the causes under discussion, they may be substantially eliminated by natural or artificial means. In the case of the Thames, the purification of water polluted by sewage above is brought about by natural causes. The organic matter appears to be oxydized during the natural flow of the water, partly by the presence of air in the water and partly by the action of aquatic plants and animals, which have the effect to destroy all noxious elements in the course of ten or twelve miles or even in a less distance.

It is asserted by some authorities that when sewage is present to the extent of one-twentieth of the flowage of the river, it becomes undiscoverable after flowing ten or twelve miles. In cases where the flow is rapid and aeration is ensured by a disturbed condition of the surface, even a larger proportion than one-twentieth may be received into the water and undergo combustion by oxygen, leaving behind no noxious elements.

It was further established in this inquiry that the most refined methods of chemical analysis failed to detect any injurious element in the Thames water due to sewage. On the other hand the opinion was advanced by high authority that the germs of cholera and typhoid fever, once discharged into the river, might escape destruction or even detection, and in this way serve to propagate these terrible diseases. The Commission did not consider this proposition to be proved, neither was it disproved, and they recommend further inquiry on this point.

Their conclusion was decidedly favorable as to the quality of the Thames water

Some persons go so far as to assert that potable waters should be absolutely uncontaminated, either by human sewage or by drainage from cultivated fields. The adoption of this conclusion would as a general rule demand, that in order to preserve the health of the city population the drainage ground from which the water is derived should be kept uninhabited. This condition is plainly impossible of fulfillment. There is hardly a city in America but comes within the ban of this opinion.

Without any desire to be decisive on this point it seems reasonable to infer from the wide experience of various cities, that there is a certain amount of contamination, in reference to the flowage of the district, which is permissible and which is not injurious, or which corrects itself by natural causes. It is a question of degree, and so far there do not appear to be any well established proofs that the limit of safety has in any case been passed. If anywhere, we must expect to learn this first in the case of London, and perhaps next in Philadelphia, and in the towns which derive their supply from the Hudson.

The analysis of the San Joaquin water by Professor Price, (see page 88,) and the comparisons instituted by him with other waters, convey a clear opinion as to its quality. Its softness is a decided advantage for steam and manufacturing purposes. The sample of water which gave this analysis was taken from the river at the site of the headworks in the month of December. It is desirable to have an analysis of water taken in the later hot months, when it may be expected the worst effects of vegetable matter will be presented.

The coming autumn will also be a favorable time to determine whether there is any mingling of the salt water with fresh at any point in the vicinity of the headworks. The small amount of snow in the mountains may be expected to result in an unusually low stage of the river in September or October, when it is probable the salt line will be found to move up stream.

The mere fact that a river with an active current flows through a marshy country for a portion of its course, is not of itself a sufficient cause for condemning the use of its waters. If the water is bad, the evil results from the presence in it of one or more ingredients, either mineral or organic. There is but one reliable way to ascertain these ingredients both as to quality and quantity, and that way is by the processes of chemical analysis. When these ingredients are measured and stated, their hygienic relations can be discussed by medical men and others competent to give an opinion, with every prospect of a satisfactory conclusion.

Until the contrary be proved or made probable the presumption is fair that all large bodies of water drained from the Sierra are good.

We can now pass to a description of the means by which this water can be introduced into the city.

The distance in an air line from the city to the river is about forty-five miles, but between us and the river lies a high range of hills, through which the lowest Pass, namely Livermore, is 740 feet above the sea. The Bay of San Francisco also intervenes, and these two circumstances give rise to the greater part of the expense involved in the introduction of the San Joaquin, for they lengthen the route from 45 miles on the shortest line to 134 in one case, and to 85 in case the water is brought over Livermore Pass.

The Mt. Diablo range of mountains ends with the delta of the San Joaquin, so that it is possible to carry the water around the northern end of the mountains. It may also be forced over Livermore Pass; and these are the projects which have been submitted for your consideration. Both of these projects require a pumping system.

The first project to come under consideration has been worked out with a high degree of intelligence and industry by its projector, W. B. Hyde, C. E. His investigations have taken a wide range and have in a great measure facilitated the examination of the project, which is in some respects novel and quite extensive in its details.

The point of appropriation is at Indian Slough, just above its junction with Old river. This point has the advantage of the settling process, which has already been attributed to the action of the tides. A suitable system of headworks is to be established at this point, to permit 100,000,000 gallons daily to enter a wooden conduit, which is placed with its roof one foot below the low water plane. This conduit is 10½ feet in diameter and 12 miles in length. Its lower extremity is in the receiving basins at Marsh's Landing, where a set of pumps is established. The function of the conduit is simply to convey the water to the pumps. The conduit will be laid in a trench excavated in the tule land, and placed always below the level of the water in the river. Being always wet, the wood will be as durable as any other material, and more so than iron.

From the receiving wells a wrought iron conduit 6½ feet in diameter extends fifty-seven miles to Oakland, at which point it is only five miles from San Francisco; but in order to reach the city by land it is extended around the southern end of the Bay by way of Alviso, and follows the west shore to Sierra Point where the San Bruno mountains abut on the Bay, through an additional length of 67 miles, making an iron conduit 122 miles in length. Adding 12 miles of wood, the total length is 134 miles.

At Sierra Point the water is discharged into a receiving reservoir 28 feet above low water, at an elevation of 33 feet higher than the wells at Marsh's Landing. The pumps at the latter point must therefore lift the water to this height, increased by the head necessary to overcome the resistance to flow in the pipe. This latter element of the lift increases rapidly as the consumption grows.

Arrived in the receiving reservoir, the water is forced by a second system of pumps to reservoirs at any heights suitable for the city supply. The city occupying different levels, the reservoirs would have different heights. It is estimated that a height of 175 feet will be sufficient for the supply of three-fourths of the population, with a good working pressure in the street mains.

It should be remarked that an alternative proposition by the same author is before you, by which the Bay is crossed in an iron tunnel to be laid in a trench excavated in the mud. The construction is novel, and has never been used either here or elsewhere. It involves some features of doubtful safety, which if they do not condemn the project at least cause a safer route to be preferred at greater expense. The tunnel has been discussed in connection with other modes of crossing the Bay. A safe tunnel from Oakland would, however, save 67 miles of conduit, and would also save pumping at Marsh's Landing to the height necessary to force the water through the additional

length of pipe. This last element is inconsiderable in the early stages of supply, but it increases with accelerated importance as the consumption attains larger dimensions, as will hereafter be made apparent.

In the above is included the outline of the system.

The pumps at Marsh's Landing are designated as low service, and those at San Francisco as high service. The type of pump proposed is the Worthington. This pump has a history in the records of a number of Eastern cities which enables us to know what to expect of it. It has never given so high a duty as some other engines, but its simplicity and convenience have given it a well deserved reputation. The question as to the character or type of pump to be preferred may remain open for future discussion, but all the calculations which follow are based upon the use of the Worthington pump.

It is sometimes asserted that a gravitation system is in itself to be preferred to a pumping system. The choice between them must, however, be held to rest upon their relative economy. It is a sound proposition that, other things being equal, the cheapest is the best for the interests of the community. To the people it makes little difference whether the water rates go to pay for coal or for interest, but they are very much concerned in the amount of these water rates.

The route of the iron conduit is by way of the shore line of the Bay, passing through or near Antioch, Martinez, Oakland, Alviso and Menlo Park, to Sierra Point. The line will be generally but a few feet above high-water mark. The country through which the line passes is generally favorable, being a plain, sloping gently to the Bay. The portion of the line on the Straits of Carquinez, five or six miles in length, is precipitous and will give rise to some difficulties. The pipe will be laid in a trench and covered with four feet of earth. In passing along the face of the bluffs which form the shore of the Straits of Carquinez, the line will generally be inside of the railroad, and a considerable portion will be made up of short tunnels.

Small streams will be passed on a masonry culvert, the drainage passing below. Larger creeks may be passed on a bridge. Navigable channels, such as Oakland Harbor if it is crossed, must be passed either by a syphon or preferably by a tunnel. The line may pass in rear of the head of Oakland Harbor.

In all cases where the pipe is not in a trench, it will be covered from the direct action of the sun by a wooden roof. The pipe may be either riveted or welded. If riveted, the longitudinal seam will be double. The round seam will be made with butt-joints, covered by a T strap riveted on, which occurring at least every four feet will add the necessary stiffness to the pipe. These pieces will be joined in this way in convenient lengths of about 24 feet, which will in turn be united in the trench by a flange joint with a ring of rubber packing, or by a bell joint, as may be found most advisable under the circumstances of the foundation.

The works, which are offered to the city for the sum of $13,000,000, are as follows, namely:

The HEADWORKS and CONDUIT 12 miles long, leading from headworks to Marsh's Landing, capable of carrying 100 millions of gallons daily.

Two RECEIVING WELLS in brick masonry at Marsh's Landing, arranged with parts and connections necessary to sustain a delivery of 100 millions of gallons daily.

Brick ENGINE AND BOILER HOUSES at Marsh's Landing, arranged to accommodate Worthington machinery capable of delivering to San Francisco 40 millions of gallons daily.

Low SERVICE PUMPING MACHINERY sufficient to deliver 20 millions of gallons daily.

Wharf, WOODEN TENEMENT BUILDINGS, COAL SHEDS, as described in their proposition.

An IRON CONDUIT 6½ feet in diameter, 122 miles (more or less) in length, double riveted, to carry—with a strain not exceeding 12,500 lbs. on the sectional inch—45 millions of gallons per day.

Such STOP GATES, AIR VALVES and BLOW-OFFS as may prove to be necessary.

At or near San Francisco a RECEIVING RESERVOIR, size not definitely stated.

City PUMPING MACHINERY for delivering 20 millions of gallons to the distributing reservoirs or to the city mains.

Fire-proof ENGINE HOUSES sufficient to accommodate machinery for 40 millions of gallons daily.

Coal WHARF, with suitable arrangements for transferring coal economically to the coal sheds.

A TELEGRAPH LINE to the headworks.

It is understood from papers filed with the Commissioners, although it is not directly stated in the proposition of the Company, that the Company is prepared to supply a conduit with a welded straight seam, capable of standing a strain of 18,000 lbs. to the sectional inch, instead of the double riveted seam. The maximum delivery of the pipe, having the same thickness of iron, with an allowed strain of 18,000 lbs., would be increased from 47 to 55 millions of gallons daily.

It will be understood that when the consumption reaches 20 millions of gallons a day it will be necessary for the city to increase the pumping power, both at Marsh's Landing and at San Francisco, and continue to add to it as the consumption grows.

The capacity of the conduit being 55 millions of gallons, it will be necessary when this consumption is reached to increase its carrying capacity. This

may be done without duplicating the whole conduit at once, but by duplicating it in sections, thus saving a considerable interest account on capital expended. The first duplication may be made of 51 miles on the lower end of the conduit. This will consist of another conduit laid alongside of the first, and united to it at a point 51 miles from Sierra Point. The lift at Marsh's Landing will be so reduced by this duplication that 68 millions of gallons a day may be passed within the prescribed limit of pressure.

At this period of consumption it will be necessary to make another extension towards Marsh's Landing. Extending it 34 miles we will have the line duplicated on 85 miles, and the delivery can now be as much as 82 millions of gallons.

When this consumption is reached the remaining 37 miles may be added, which will give a capacity of 110 millions of gallons a day.

A somewhat shorter extension would limit the capacity to 100 millions of gallons, which is the estimated delivery of the conduit from the headworks to Marsh's Landing.

The first extension adds 12 millions of gallons a day to the delivery. This will probably meet the growth of the city for eight years. The second extension adds 14 millions of gallons, which would serve perhaps for 10 years more; and the third, supposing the delivery limited to 100 millions of gallons, would suffice for perhaps 12 years. The extension of the conduit would therefore be extended over 18 years. If it were necessary to duplicate the whole conduit when a consumption of 55 millions of gallons is reached, it is plain that the works would have thereafter to bear the interest on the whole cost, whereas by the proposed arrangement the expenditure can be limited to three or more equal parts, upon which interest will accrue only as the consumption requires. This is a manifest advantage, in a financial point of view.

The work of the lower service pumps will result from the following considerations:

To enable the conduit to deliver 10 millions of gallons a day the fall in 122 miles will be 6¾ feet. Twenty (20) millions of gallons a day will require a fall of 27 feet, and 55 millions of gallons a fall of 200 feet. Inasmuch as the point of delivery near San Francisco is 33 feet higher than the inlet valves of the pumps at Marsh's Landing, all the water will have to be lifted to this height plus the head required to cause the necessary flow.

The following table states the pump lift and the corresponding effective horse-power of the low service engines for different rates of delivery:

TABLE I.

Daily Delivery.	Corresponding Pump-Lift.	Effective Horse-Power Required.	Daily Delivery.	Corresponding Pump-Lift.	Effective Horse-Power Required.
Mill. Galls.	Feet.		Mill. Galls.	Feet.	
10	39.75	70	60	198	2,087
15	47	124	68	245	2,929
20	60	210	Here enters	2d Extension, 34	miles.
25	75	328	70	189	2,327
30	93	491	82	246	3,554
35	115	707	Here enters	3d Extension.	
40	140	983	84	151	2,226
45	168	1,329	90	168	2,658
50	200	1,758	100	200	3,516
55	235	2,271	110	235	4,542
Here enters Conduit.	1st Extension of	51 miles of			

The accompanying profile is approximately correct as to the line of the conduit, and illustrates the pressures which will be on the different parts of the pipe under the maximum delivery of 55 millions of gallons. The thicknesses of the pipe in its different parts are also shown.

The scheme of low service pumps and boilers in action and reserve, the consumption of coal, and other expenses proposed by the Company for different deliveries are shown in Table 2.

The consumption of coal results from an hourly allowance of 7 lbs. of Mt. Diablo screenings to each horse-power. The cost of screenings is assumed to be $5.25 per ton average for both stations.

The tables that follow No. 2 represent the position assumed by the San Joaquin and San Francisco Water Works, in all matters that affect the cost of pumping. Taken in their order of sequence they will readily be understood.

The cost of pumping appears to be fairly estimated in these tables. Some question may perhaps be raised as to the smallness of the labor account.

The San Francisco service is calculated on the basis that ¾ of the supply is delivered at a height of 170 feet, ⅛ at a height of 250 feet, and ⅛ at a height of 350 feet. These elevations with a proper pipe system will be entirely adequate for all purposes.

TABLE II.

SHOWING THE GENERAL SCHEME OF PUMPING AT THE LOW SERVICE WORKS.

Million Galls. Pumped Daily	Total Horse-Power required.	Number and Character of Pumps in Action.	Number and Character of Pumps in Reserve.	Number of 150 horse-power each Boilers in action	Number of 150 horse-power each Boilers in reserve	Dimension of Engine House Floor at 40'x20' for each Engine, each pair end to end, and pairs side by side	No. of Engineers and Assistants under pay	No. of Tons Screenings to be handled annually	No. of Firemen under pay	No. of Helpers under pay	No. of Oilers and Wipers	No. of 4-ft. Gas Jets in use in Engine Room	No. of 4-ft. Gas Jets in use in Fire Room	No. of feet of Gas, at 10 hours daily, consumed annually	Annual cost of Gas or equivalent in Oils, at $3.50 and $3.00
10	70	1 20-Million Engine of 250 horse-power.	1 20-Million Engine of 250 horse-power.			80'x20'	2	1917	2	1	..	4	2	M. 87.7	$307
11	80					“	2	2191	2	1	..	4	2	......	....
12	92					“	2	2519	2	1	..	4	2	......	....
13	101			1	1	“	2	2766	2	1	..	4	2	......	....
14	114					“	2	3122	2	1	..	4	2	......	....
15	124					“	2	3396	2	1	..	4	2	......	....
16	140					“	2	3834	2	1	..	4	2	......	....
17	157					“	2	4299	2	1	..	4	2	......	....
18	172					“	2	4710	2	1	..	4	2	......	....
19	191					“	2	5230	2	1	..	4	2	......	....
20	210			2	1	“	2	5650	2	1	..	4	2	$3.00	....
21	231	2 15-Million Engines of 250 horse-power each (The first 2 altered.)	1 20-Million Engine of 500 horse-power.			80'x40'	2	6225	2	1	1	6	2	116.8	$350
22	253					“	2	6928	2	1	1	6	2	......	....
23	277					“	2	7585	2	1	1	6	2	......	....
24	302					“	2	8269	2	1	1	6	2	......	....
25	328					“	3	8981	2	1	1	6	2	......	....
26	357					“	3	9775	2	1	1	6	2	......	....
27	387			3	2	“	3	10596	2	1	1	6	2	......	....
28	420					“	3	11500	2	1	1	6	2	......	....
29	455					“	3	12458	2	1	1	6	2	......	....
30	491					“	3	13443	2	1	1	6	2	......	....
31	530	1 20-Million Engine of 500 horse-power and 2 10-Million Engines of 250 horse-power each. (The 2 15-Millions altered.)				“	3	14512	2	1	1	6	2	......	....
32	571			4	2	“	3	15634	2	1	1	6	2	......	....
33	613					“	3	16784	2	1	1	6	2	M.	
34	659					“	3	18054	4	2	1	6	3	131.4	$395
35	707		1 20-Million Engine of 750 horse-power.	5		“	3	19358	4	2	1	6	3	......	....
36	756				2	“	3	20700	4	2	1	6	3	......	....
37	809					“	3	22151	4	2	1	6	3	......	....
38	869					“	3	23794	4	2	1	6	3	......	....
39	923			6	2	“	3	25272	4	2	1	6	3	......	...
40	983					“	3	26915	4	2	1	6	3	M.	
41	1046	2 20-Million Engines of 750 horse-power each, and 1 10-Million of 250 horse-power.	1 20-Million Engine of 500 horse-power, 1 10-Million of 250 H. P.			80'x60'	3	28640	4	2	2	8	5	190	$570
42	1113					“	3	30940	4	2	2	8	5	......	....
43	1182			9	3	“	3	32364	4	2	2	8	5	......	....
44	1255					“	3	34362	4	2	2	8	5	......	....
45	1329					“	3	36388	6	3	2	8	5	......	....
46	1410					“	3	38606	6	3	2	8	5	......	....
47	1491			10	3	“	3	40824	6	3	2	8	5	......	....
48	1577					“	3	43179	6	3	2	8	5	M.	
49	1665			11	4	“	3	45588	6	3	2	8	6	205	$615
50	1758			12	4	“	3	48135	6	3	2	8	6	.....	....
51	1816	3 15-Mills. of 750 H. P. each and 1 10-Mill. of 500 H. P. (20-Millions altered.)	1 15-Mill. of 750 H. P. 2 5-Mills. of 250 H. P. (10 Mills. altered.)	12	4	80'x80'	3	49722	6	3	2	8	6	M.	
52	1950			13	5	“	3	53390	6	3	2	8	7	219	$657
53	2066			14	5	“	3	56568	8	4	2	8	7	......	....
54	2161			14	5	“	3	59168	8	4	2	8	7	M.	
55	2271			15	5	“	3	62179	8	4	2	8	8	234	$702
56	2385	4 15-Million at 750 H. P.	1 10-Million at 500 H. P. 2 5-Million at 250 H. P. 1 15-Million at 750 H. P.	16	5	“	3	65299	8	4	2	8	8	......	....

TABLE III.

SHOWING SUNDRY EXPENSES OF PUMPING AT THE LOW SERVICE WORKS.

Million Gallons Pumped Daily.	Horse-Power required for the Work........	Cost per horse-power per annum on account of Oils, Waste, Packing, etc.........	Estimated Annual Expense of Labor at Pump Works.... ..	Cost per horse-power per annum on account Labor...........	Estimated Annual Expense of Illumination...........	Cost per horse-power per annum on account of Illumination..	Total Cost per horse-power per annum on account of preceding...........
10	70	$5 00	$6420	$97 72	$307	$4 39	$101 11
11	80	"	"	80 25	"	3 75	89 00
12	92	"	"	70 00	"	3 34	78 34
13	101	"	"	62 16	"	3 04	70 20
14	114	"	"	56 32	"	2 70	64 02
15	124	"	"	51 80	"	2 48	59 12
16	140	"	"	45 90	"	2 20	53 10
17	157	"	"	40 90	"	1 96	47 86
18	172	"	"	37 32	"	1 78	44 10
19	191	"	"	33 61	"	1 61	40 21
20	210	"	"	30 57	"	1 46	37 03
21	231	"	7260	31 43	350	1 52	37 95
22	253	"	"	28 70	"	1 38	35 08
23	277	"	"	26 21	"	1 27	32 48
24	302	"	"	24 04	"	1 16	30 20
25	328	"	9070	27 65	"	1 07	33 72
26	357	"	"	25 41	"	98	31 39
27	387	"	"	23 44	"	91	29 35
28	420	"	"	21 60	"	83	27 43
29	455	"	"	19 94	"	77	25 71
30	491	"	"	18 48	"	71	24 19
31	530	"	"	17 11	"	66	22 77
32	571	"	"	15 89	"	62	21 51
33	613	"	"	14 80	"	57	20 37
34	659	"	11,890	18 04	395	60	23 64
35	707	"	"	16 82	"	56	22 38
36	756	"	"	15 73	"	52	21 25
37	809	"	"	14 70	"	49	20 19
38	869	"	"	13 68	"	46	19 14
39	923	"	"	12 89	"	43	18 32
40	983	"	"	12 10	"	40	17 50
41	1046	"	12,730	12 17	570	54	17 71
42	1113	"	"	11 44	"	51	16 95
43	1182	"	"	10 77	"	50	16 27
44	1255	"	"	10 14	"	46	15 60
45	1329	"	15,670	11 79	"	43	17 22
46	1410	"	"	11 11	"	41	16 52
47	1491	"	"	10 51	"	38	15 89
48	1577	"	"	9 93	"	36	15 29
49	1665	"	"	9 41	615	37	14 78
50	1758	"	"	8 92	"	35	14 27
51	1816	"	"	8 63	"	34	13 97
52	1950	"	"	8 04	657	34	13 38
53	2066	"	18,490	8 95	"	32	14 27
54	2121	"	"	8 56	"	30	13 86
55	2271	"	"	8 15	702	31	13 46
56	2385	"	"	7 76	"	30	13 06

TABLE IV.

SHOWING THE COST OF PUMPING LOW SERVICE WORKS.

Million Gallons Delivered Daily	Total Million Gallons Delivered Annually	Horse-power required to do Work	No. of Tons (2240 lbs.) Coal per horse-power per annum, at 7 lbs. per horse-power per hour (Screenings)	Cost of Coal per horse-power per Annum, at $5.25 per ton	Total Cost Fuel Annually	Cost per horse-power per annum for Labor, Miscellaneous, etc., etc. (See Table III)	Total Cost of Labor, Miscellaneous, etc.	Final Total Cost of Pumping, Low Service	Cost in Cents per Million Gallons raised 1 ft. high
10	3,650	70	27.38	$143 75	$10,064	$101 11	$7,077	$17,141	11.77
11	4,015	80	"	"	11,503	89 00	7,127	18,630	11.19
12	4,380	92	"	"	13,225	78 34	7,187	20,412	10.68
13	4,745	101	"	"	14,322	70 20	7,232	21,554	10.28
14	5,110	114	"	"	16,391	64 02	7,297	23,688	9.99
15	5,475	124	"	"	17,829	59 12	7,347	25,176	9.75
16	5,840	140	"	"	20,120	53 10	7,427	27,556	9.47
17	6,205	157	"	"	22,570	47 86	7,512	30,082	9.21
18	6,570	172	"	"	24,730	44 10	7,587	32,317	9.03
19	6,935	191	"	"	27,458	40 21	7,682	35,140	8.85
20	7,300	210	"	"	29,663	37 03	7,777	37,440	8.69
21	7,665	231	"	"	32,681	37 95	8,765	41,446	8.74
22	8,030	253	"	"	36,372	35 08	8,875	45,247	8.60
23	8,395	277	"	"	39,821	32 48	8,995	48,816	8.47
24	8,760	302	"	"	43,412	30 20	9,120	52,532	8.37
25	9,125	328	"	"	47,150	33 72	11,060	58,210	8.53
26	9,490	357	"	"	51,319	31 39	11,205	62,524	8.42
27	9,855	387	"	"	55,629	29 35	11,355	66,984	8.32
28	10,220	420	"	"	60,375	27 43	11,520	71,895	8.23
29	10,585	455	"	"	65,407	25 71	11,695	77,102	8.15
30	10,950	491	"	"	70,576	24 19	11,875	82,450	8.08
31	11,315	530	"	"	76,188	22 77	12,070	88,258	8.01
32	11,680	571	"	"	82,079	21 51	12,275	94,354	7.95
33	12,045	613	"	"	88,116	20 37	12,485	100,601	7.89
34	12,410	659	"	"	94,784	23 64	15,580	110,364	8.05
35	12,775	707	"	"	101,630	22 38	15,820	117,450	7.99
36	13,140	756	"	"	108,675	21 25	16,065	124,740	7.93
37	13,505	809	"	"	115,293	20 19	16,330	131,623	7.88
38	13,870	869	"	"	123,919	19 14	16,630	140,549	7.83
39	14,235	923	"	"	132,678	18 32	16,900	149,578	7.79
40	14,600	983	"	"	141,304	17 50	17,200	158,504	7.75
41	14,965	1046	"	"	150,360	17 71	18,530	168,890	7.76
42	15,330	1113	"	"	162,435	16 95	18,865	181,300	7.73
43	15,695	1182	"	"	169,911	16 27	19,210	189,121	7.69
44	16,060	1255	"	"	180,401	15 60	19,575	199,976	7.66
45	16,425	1329	"	"	191,037	17 22	22,885	213,922	7.74
46	16,790	1410	"	"	202,682	16 52	23,290	225,972	7.71
47	17,155	1491	"	"	214,326	15 89	23,695	238,021	7.68
48	17,520	1577	"	"	226,690	15 29	24,125	250,815	7.65
49	17,885	1666	"	"	239,337	14 78	24,610	263,947	7.62
50	18,250	1758	"	"	252,709	14 27	25,075	277,784	7.60
51	18,615	1810	"	"	261,041	13 97	25,365	286,406	7.59
52	18,980	1950	"	"	280,298	13 38	26,077	306,375	7.56
53	19,345	2066	"	"	296,982	14 29	29,477	326,459	7.60
54	19,710	2101	"	"	310,640	13 86	29,952	340,592	7.58
55	20,075	2271	"	"	326,430	13 46	30,547	356,977	7.56
56	20,440	2385	"	"	342,820	13 06	31,117	373,937	7.54

TABLE V.

SHOWING COST OF PUMPING AT LOW SERVICE WORKS, WITH ALLOWANCE OF 10 PER CENT. ON MACHINERY FOR INTEREST AND REPAIRS.

Million Gallons Delivered Daily....	Total Million Gallons Delivered Annually	Annual Current Pumping Expense. (Table IV.)...	Standing Cost of Machinery to Supply Demand.......	Interest & Renewal Charges on Machinery at 6+4=10 per cent. per annum.....	Total Cost of Low Service Pumping...............	Cost in Cents per 1000 Gallons Pumped ....
10	3,650	$17,141	$125,000	$12,500	$29,641	.81
11	4,015	18,650	"	"	31,130	.78
12	4,380	20,412	"	"	32,912	.75
13	4,745	21,554	"	"	34,054	.72
14	5,110	23,688	"	"	36,188	.71
15	5,745	25,176	"	"	37,676	.69
16	5,840	27,556	"	"	40,057	.69
17	6,205	30,082	"	"	42,582	.69
18	6,570	32,317	"	"	44,817	.69
19	6,935	35,140	"	"	47,640	.69
20	7,300	37,440	"	"	49,940	.68
21	7,665	41,446	210,000	21,000	62,446	.81
22	8,030	45,247	"	"	66,247	.82
23	8,395	48,816	"	"	69,816	.83
24	8,760	52,532	"	"	73,532	.84
25	9,125	58,210	"	"	79,210	.87
26	9,490	62,524	"	"	83,524	.88
27	9,855	66,984	"	"	87,984	.89
28	10,220	71,895	"	"	92,895	.91
29	10,585	77,102	"	"	98,102	.93
30	10,950	82,450	"	"	103,450	.95
31	11,315	88,258	311,750	31,175	119,433	1.06
32	11,680	94,354	"	"	125,529	1.08
33	12,045	100,601	"	"	131,779	1.09
34	12,410	110,364	"	"	141,539	1.14
35	12,775	117,450	"	"	148,625	1.17
36	13,140	124,740	"	"	155,915	1.19
37	13,505	131,623	"	"	162,798	1.21
38	13,870	140,549	"	"	171,724	1.24
39	14,235	149,518	"	"	180,753	1.27
40	14,606	158,504	"	"	189,679	1.30
41	14,965	168,890	403,500	40,350	209,240	1.40
42	15,330	181,300	"	"	221,650	1.45
43	15,695	189,121	"	"	229.471	1.46
44	16,060	199,976	"	"	240,326	1.50
45	16,425	213,922	"	"	254,272	1.55
46	16,790	225,972	"	"	266,322	1.59
47	17,155	238,021	"	"	278.371	1.62
48	17,520	250,815	"	"	291,165	1.66
49	17,885	263,947	"	"	304,297	1.70
50	18,250	277,784	"	"	318,134	1.74
51	18,615	286,406	587,000	58,700	345,106	1.85
52	18,980	306,375	"	"	365,075	1.92
53	19,345	326,459	"	"	385,159	1.99
54	19,710	340,592	"	"	399,292	2.03
55	20,075	356,977	"	"	415,677	2.07
56	20,440	373,937	678,750	67,875	441,812	2.16

TABLE VI.

SHOWING COST OF PUMPING AT SAN FRANCISCO WORKS.

Million Gallons Delivered Daily	Required Horse-Power.. ..	No. of Tons (2240 lbs.) Coal, (Screenings) per horse-power per annum at 7 lbs. per horse-power per hour.	Total Tons Coal Annually Required to do Work....	Total Cost of Fuel Annually	Total Cost Labor, Etc	Total Cost S. F. Pumping..	Cost in Cents per Million Gallons Raised 1 Foot....	Standing Cost of Machinery	Annual Cost of Machinery including Interest and Renewals—10 per cent.....	Final Total Cost of S. F. Pumping Works.........	Cost in Cents per 1000 Gallons................
10	356	27.38	9,747	$51,174	$14,952	$66,126	8.98	$210,000	$21,000	$87,126	2.39
11	391	"	10,705	56,206	15,249	71,455	....	"	"	92,455	2.30
12	427	"	11,691	61,382	15,372	76,754	....	"	"	97,754	2.23
13	462	"	12,649	66,407	15,708	82,115	....	260,000	26,000	108,115	2.28
14	498	"	13,635	71,584	15,936	87,520	....	"	"	113,520	2.22
15	533	"	14,593	76,614	15,990	92,604	8.35	300,000	30,000	122,604	2.24
16	569	"	15,579	81,790	16,501	98,291	....	"	"	128,291	2.20
17	604	"	16,537	86,819	16,912	103,731	....	"	"	133,731	2.12
18	640	"	17,523	91,996	16,640	108,636	....	"	"	138,636	2.11
19	675	"	18,481	97,000	16,875	113,875	....	"	"	143,875	2.07
20	711	"	19,467	102,202	17,064	119,264	8.06	300,000	30,000	149,264	2.04
21	746	"	20,425	107,231	17,904	125,135	....	360,000	36,000	161,135	2.10
22	782	"	21,411	112,408	18,768	131,176	....	"	"	167,176	2.08
23	817	"	22,369	117,437	18,791	136,228	....	"	"	172,228	2.05
24	853	"	23,355	122,614	19,619	142,233	....	"	"	178,233	2.04
25	889	"	24,313	127,643	20,447	148,090	8.01	410,000	41,000	189,090	2.06
26	924	"	25,299	132,820	21,252	154,072	....	"	"	195,072	2.06
27	960	"	26,257	137,849	22,080	159,929	....	"	"	200,929	2.04
28	995	"	27,243	143,026	22,885	165,911	....	"	"	206,911	2.02
29	1031	"	28,201	148,055	23,713	171,768	....	"	"	212,768	2.01
30	1066	"	29,187	153,232	23,452	176,684	7.97	"	"	217,684	1.99
31	1102	"	30,172	158,403	24 244	182,647	....	"	"	223,647	1.97
32	1138	"	31,158	163,579	23,898	187,477	....	"	"	228,477	1.96
33	1173	"	32,117	168,614	24,633	193,247	....	"	"	234,247	1.94
34	1209	"	33,102	173,785	24,180	197,965	....	"	"	238,965	1.93
35	1244	"	34,062	178,826	24,880	203,706	7.87	470,000	47,000	250,706	1.96
36	1280	"	35,046	183,992	25,600	209,592	....	"	"	256,592	1.96
37	1315	"	36,005	189,026	24,985	214,011	....	"	"	261,011	1.93
38	1351	"	36,990	194,198	25,669	219,867	....	"	"	266,867	1.92
39	1387	"	37,076	199,374	26,353	225,727	....	"	"	272,727	1.92
40	1422	"	38,934	204,404	25,596	230,000	7.77	"	"	277,000	1.90
41	1458	"	39,920	209,580	26,244	235,824	....	"	"	282,824	1.86
42	1493	"	40,850	214,462	26,874	241,336	....	530,000	53,000	294 336	1.92
43	1529	"	41,864	219,786	25,993	245,779	....	"	"	298,779	1.90
44	1564	"	42,822	224,815	26,588	251,403	....	"	"	304,403	1.90
45	1600	"	43,868	230,307	27,200	257,507	7.73	"	"	310,507	1.90
46	1635	"	44,738	234,775	27,795	262,570	....	"	"	315,570	1.90
47	1671	"	45,752	240,198	28,407	268,605	....	"	"	321,605	1.90
48	1706	"	46,710	245,228	29,002	274,230	....	580,000	58,000	332,230	1.90
49	1742	"	47,696	250,404	29,614	280,018	....	"	"	338,018	1.90
50	1778	"	48,626	255,287	30,228	285,515	7.73	"	"	343,515	1.88
51	1814	"	49,607	260,752	29,024	289,776	....	"	"	347,776	1.87
52	1849	"	50,598	265,590	29,584	295,174	....	"	"	353,174	1.86
53	1885	"	51,611	270,958	30,160	301,118	....	"	"	359,118	1.86
54	1920	"	52,514	275,699	30,720	306,419	...	"	"	364,419	1.85
55	1956	"	53,555	281,164	31,296	312,460	....	"	"	370,460	1.85
56	1990	"	54,486	286,052	29,850	315,902	7.63	600,000	60,000	375,902	1.83

The general arrangements by which the water is delivered to the city appear to be practicable, convenient and simple. The conduit becomes assimilated to a reversed syphon by the fact that it is placed under pressure by the action of the pumps. This pressure is relieved when the pumps cease to act. The pressure on the conduit increases as the head, against which the low service pump acts, increases. This pressure does not become important until the delivery becomes considerable.

The question of admissible strain on the conduit enters here as in the other lines. A welded pipe is assumed to stand a strain of 18,000 lbs. per sectional inch. A factor of safety of 2½ has been required for the gravitation lines. A similar rule applied in this case would require the straight seam of the welded pipe to have a strength of 45,000 lbs. to the sectional inch. If the strength of the seam were less, the strain of 18,000 lbs. would be inadmissible. The manufacturers of these welded tubes claim to make the joint as strong as the iron. This strength would have to be assured by test. The strength of the portion of the conduit which receives the shock of the pump will probably require an increase. This shock is very much reduced by the peculiar action of the Worthington Duplex pump.

With gates and exit valves every four or five miles, it is thought that the water may be controlled and regulated with safety, so that any portion of the conduit needing repair can be entered and examined.

A telegraph line would be with this as with the other lines indispensable.

The details of this work would be very numerous. The style of headworks, the arrangement of the receiving tanks, foundations and joints of pipes, arrangements of gates, and many other points of importance, would necessarily be left to future adjustment.

Since the preceding scheme was prepared and described a physical change of an important character has taken place in the San Joaquin River, which affects the project in some degree and which therefore deserves notice.

The map shows the San Joaquin just below Banta to divide into three channels, separated by islands several miles in width. Old River is the westerly channel. It has until within a few months been closed at its head by a raft or obstruction, which prevented the river water from entering at its head except in very high stages of the river. It received its water lower down, by sloughs connecting it with the main river. This circumstance gave to the site of the headworks a certain advantage in settling the sediment, which is borne in high stages of the river or which is due to mining.

The obstruction at the head of Old River has, however, recently been removed in the reclamation operations which are in progress on the islands, and the river water now flows down Old River in the same way as through the other channels. The water in Old River now must be regarded as subject only to the same influences as the other river water. The action of the tides in alternating the current or in varying its velocity must still serve to favor a deposit of suspended matter, but the time during which any given quantity of water is subjected to this action has been probably reduced by the change in the channel. If then it shall appear that the advantage of nat-

ural settling has been in part lost, it may be necessary to provide for the artificial clearance of the water. It is thought that the most practicable way of bringing about this result will be found in the increase of reservoir capacity at Marsh's Landing. Something will be gained by the arrangement of the conduit with wells for settlement at intervals along the line.

At St. Louis, where the muddy water of the Missouri is pumped for city uses, it is first delivered into settling tanks which hold one day's supply. After one day's rest in these tanks it is pumped again to the mains for use. It is thought that if the receiving tanks at Marsh's Landing are constructed of sufficient capacity to hold five or six days' supply, with such relief as may be necessary for the proper cleaning, all objection resulting from the changed conditions in the river at the headworks will be satisfactorily obviated.

ANALYSIS OF THE WATER OF THE SAN JOAQUIN RIVER, BY PROF. THOMAS PRICE, DECEMBER, 1876.

The water has a slight turbid appearance when first taken out of the river. On standing in a vessel for a short time it settles and becomes very clear.

COMPOSITION PER GALLON OF 231 CUBIC INCHES.

Carbonate of Lime	1.607	grains.
Carbonate of Magnesia	.377	"
Sulphate of Lime	1.133	"
Chloride of Sodium	1.688	"
Potash, Iron and Alumina	Traces.	
Silica	.102	"
Organic Matter	1.005	"
Total	5.912	grains.
Hardness before boiling	$3\frac{1}{2}$°	
Hardness after boiling	2°	
Free Ammonia per gallon of 231 cubic inches	.0025	grains.
Albumenoid Ammonia per gallon of 231 cubic inches	.0016	"
Nitrates	Traces.	

MATTER HELD IN SUSPENSION PER GALLON OF 231 CUBIC INCHES.

Organic Matter	.015	grains.
Inorganic Matter	.018	"
	.033	grains.

From the foregoing analysis it is evident that the water is of a very superior quality, for both industrial and domestic purposes, being free from all objectionable ingredients that could in any way affect the health of persons using it.

The very small quantity of inorganic matter contained makes it a most valuable water for steam purposes.

COMPARISONS WITH OTHER WATERS.

CROTON WATER, NEW YORK, ANALYZED BY DR. CHANDLER.

	Grains per Gallon of 231 cub. inches.
Chloride of sodium	0.402
Sulphate of potassa	0.179
Sulphate of soda	0.260
Sulphate of lime	0.158
Bicarbonate of lime	2.670
Bicarbonate of magnesia	1.913
Silica	0.621
Alumina and oxide of iron	trace
Organic matter	0.670
Total	6.873

OTHER WATERS.

SOURCE.	Inorganic Matter. Grains per Gallon.	Organic Volatile Matter. Grains per Gallon.	Total Solid per Gallon. Grains per Gallon.
New York (Croton)	3.90	0.66	4.56
New York (Croton)	3.31	1.14	4.45
New York (Croton)	4.11	0.67	4.78
New York (well west of Central Park)	38.95	4.55	43.50
Brooklyn (Ridgwood)	3.37	0.59	3.92
Boston (Cochituate)	2.40	0.71	3.11
Philadelphia (Fairmount, Schuylkill)	2.30	1.20	3.50
Philadelphia (Delaware)	2.93	0.55	3.48
Albany (hydrant)	8.47	2.31	10.78
Troy (hydrant)	6.09	1.34	7.43
Utica (hydrant)	5.50	0.96	6.46
Syracuse (new reservoir)	12.13	1.80	13.93
Cleveland (Lake Erie)	4.74	1.53	6.27
Chicago (Lake Michigan)	5.62	1.06	6.68
Rochester (Genesee River)	12.02	1.23	13.25
Schenectady (street well)	46.88	2.33	49.21
New York, Jersey City, Hoboken and Hudson City (Passaic River)	4.58	2.86	7.44
Trenton (Delaware River)	2.93	0.55	3.48
London (Thames River)	15.55	0.83	16.38
London (street well)	90.38	9.59	99.97
Dublin	1.77	1.34	3.11
Paris (Seine above city)	7.83	1.00	8.83
Amsterdam (River Vecht)	14.45	2.13	16.58
Amsterdam (deep well)	64.55	4.38	68.93
San Francisco (well on Market street)	44.25	2.15	46.40
San Francisco (Spring Valley hydrant)	7.42	0.78	8.20
Clear Lake	7.38	1.97	9.35

ANALYSIS OF WATER SUPPLIED TO THE CITY OF LONDON.

By Drs. Frankland, Lethby and Hoffmann.

Carbonate of lime	6.26	8.13	5.61	3.96
Sulphate of lime	2.58	1.83	8.82	....
Nitrate of lime	0.01	0.58	0.03	0.06
Carbonate of magnesia	0.87	1.21	2.73	2.83
Chloride of sodium	1.38	1.41	2.80	5.23
Sulphate of soda	1.20	0.74	....	12.11
Chloride of potassium	....	....	0.35	....
Sulphate of potassa	0.89	1.00	0.56	1.12
Carbonate of potassa	....	....	....	1.44
Silica	0.40	0.50	0.61	0.06
Iron, alumina and phosphates	Trace.	0.38	Trace.	Trace.
Ammonia	Trace.	Trace.	Trace.	Trace.
Organic matter	2 23	3.30	2.10	1.47
Total residue per gallon	15.82	19.08	23.61	28.28

ANALYSIS OF CLEAR LAKE WATER BY THOMAS PRICE, OF SAN FRANCISCO.

	Grains per Gallon of 231 cub. inches.
Carbonate of lime	2.554
Carbonate of magnesia	2.683
Carbonate of soda	0.728
Alumina and iron	0.012
Chloride of potassium	0.261
Chloride of sodium	0.342
Sulphate of lime	0.341
Silica	0.464
Organic matter	1.970
Boracic acid	trace.
Phosphoric acid	trace.
Total solids	9.355

Organic Matter.

Free ammonia	0.0034
Albumenoid ammonia	0.0012

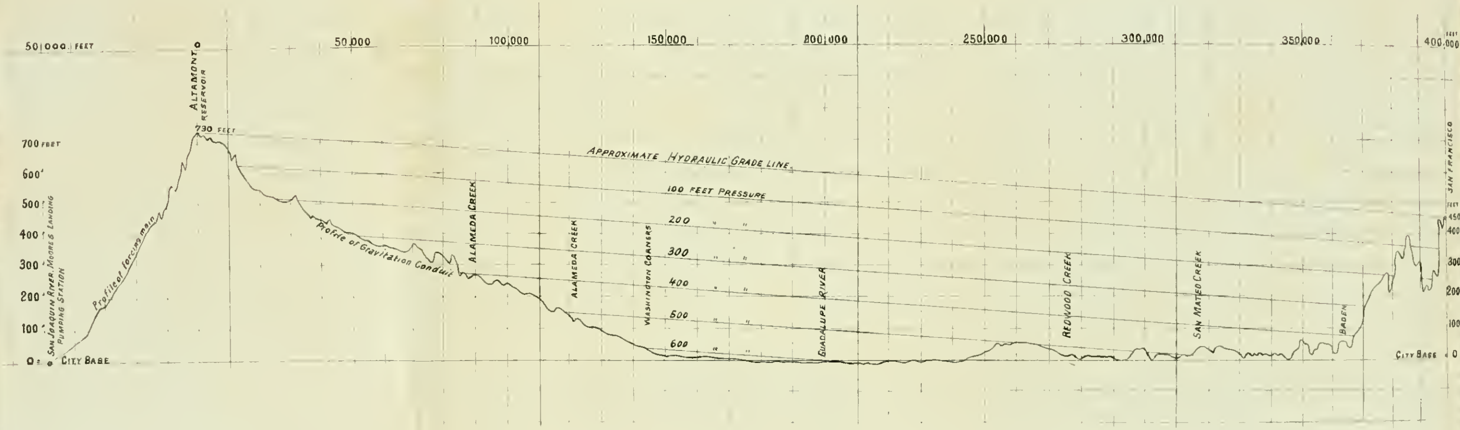
Contains only very minute traces of nitrates and nitrites.

Conclusions.

It is apparent from the foregoing that the composition of the San Joaquin River water compares most favorably with that supplied to other leading cities of both hemispheres, and for domestie purposes is in no way inferior to the waters of the Sierra Nevada Mountains.

PROFILE of FORCING MAIN & CONDUIT for WATER SUPPLY from the SAN JOAQUIN RIVER at MOORE'S Landing, to San Francisco by way of Livermore Pass and the head of the Bay.

Horizontal scale 1 inch to 40,000 feet
Vertical scale 1 inch to 400 feet.



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SUPPLY FROM THE SAN JOAQUIN RIVER BY WAY OF LIVERMORE PASS.

This route is more direct than the one just described. Instead of heading the mountains, it proposes to cross them. The length is 84 miles which saves 50 miles in conduit, as compared with the other route.

The project consists in the establishment of pumps at Moore's Landing on the San Joaquin, Old River, about nine miles above the headworks of the other San Joaquin project. The pumps are to force the water over Livermore Pass, which is 735 or 740 feet above the low water in the river, through a force main nine miles in length, having a diameter of 54 inches. At or near this point the water is delivered into a reservoir having an estimated capacity of 1,000 millions of gallons. A conduit of wrought iron, 75 miles in length and 53 inches in diameter, is to connect this reservoir with a city reservoir placed at 450 feet elevation. The fall will be 3⅓ feet per mile.

It has already been established that a height of 300 feet is the more desirable and economical for the level of the discharge in the city. This fact will work to the advantage of the project, in lessening the size of the conduit or in increasing its discharge.

It will be seen that the project contemplates both gravitation and pumping. The route of the conduit from Livermore Pass to the city is identical with the other lines which cross Livermore Pass. The project proposes to deliver 25 millions of gallons daily.

We are enabled to compare the actual amounts of work which the pumps must do for equal deliveries, in the two San Joaquin projects. Recalling the lifts at the low service works necessary to force the water from Marsh's Landing to San Francisco, and allowing 200 feet for the mean lift at San Francisco, we have the following table of work in million foot gallons, for daily consumption running from 10 to 25 millions in steps of five millions. The table also includes the corresponding items for the Livermore Pass route, where all the water is lifted 740 feet.

Daily Consumption.	San Joaquin and San Francisco W. W.			Livermore Pass Route.
	Work in Mill.-Foot-Galls.		Total Work in Mill.-Foot-Galls.	Total Work in Mill.-Foot-Galls.
	Low Service Pumps.	San Francisco Pumps.		
10	397	2,000	2,397	7,400
15	705	3,000	3,705	11,100
20	1,200	4,000	5,200	14,800
25	1,875	5,000	6,875	18,500

From this we see that the actual pumping work by the Livermore Pass is, for each stated delivery, more than twice that required for the longer route by Antioch and Oakland. The labor and interest account will, however, be less by the Livermore Pass route than by the other.

Now, what will it cost to raise a million of gallons 740 feet high?

The height consumed by friction for the full amount of 25 millions of gallons daily is 24 feet, making a total height of 764 feet.

In the discussion upon the Laguna de la Merced, the cost of pumping in various cities will be stated. There are great differences in the cost at different places. Local circumstances doubtless have a very considerable influence. The lowest price is at St. Louis, and was 5.18 cents for a million of gallons raised one foot. This cost is regarded as unusually low, even for St. Louis. It is understood that coal was obtained at cheaper rates than usual. It will be understood that coal is the principal element of expense in pumping operations.

In a comparison with the work in Eastern cities, the circumstances of the high lift in this project is the only point which is favorable, as far as cheapness per foot raised is concerned. In all other respects—cost of coal and labor, repairs and oils—the case compares unfavorably with most Eastern cities. The coal is not only higher in price than at most points in the East, but it is not so good.

There are no exact comparisons with other coals by which the value of Mt. Diablo screenings, which is the fuel proposed, can be determined. The hourly consumption per effective horse-power has been placed in the discussion on the other San Joaquin problem at seven lbs. The effective horse-power required to lift 25 millions of gallons per day to the height of 764 feet, is 3,360. The daily consumption of coal will be 252 tons of 2,240 lbs. The coal costs at the wharves of the Mt. Diablo mines $4 50. It may be assumed to cost $5.25 delivered at the pumping station. Adopting the same general scheme of labor, light, oil, waste and repairs, estimated at four per cent., it will be found that the cost of pumping a million of gallons one foot high, including the friction head, will be 7.9 cents, when the engines are used to the full capacity; or, otherwise stated, the cost of raising one thousand gallons to the height of Livermore Pass through the proposed force main will be 6.03 cents. When the engines are running at less than the full capacity the cost will be somewhat increased. The want of exact experiments showing the value of the Mt. Diablo screenings forces an assumption of some value upon which to base discussion. The experience of manufacturing establishments in the city indicates the value which has been assumed to be nearly true. Perhaps further discussion and experience may make a reduction justifiable. The labor account for both pumping projects is lower than the average in our Eastern cities. It results from an economical arrangement of pumps and boilers, and every labor-saving contrivance is presumed to be applied.

However these details of expenses may be found to vary in actual practice, there is a broad way of looking at this expense which will commend itself to

reflecting people. We have no reason to expect that pumping operations can be carried on here more cheaply, if as cheaply as in the East. The cost of pumping one million gallons one foot high in St. Louis was, for the six months ending April 30, 1876, 5.18 cents. This is the lowest record that is known to us. Some explanation is found in the low price of coal, which was 7½ cents a bushel. The average price for the future is assumed by the City Engineer to be nine cents a bushel. Counting 30 bushels to the ton, the cost of coal was $2.25 per ton. The quality was inferior, 2,905 lbs. being required to do the work which 1,533 did at Brooklyn, and what 2,082 lbs. did at Belmont Station, Phliadelphia. There are pretty fair general reasons for concluding that the quality of this St. Louis coal does not differ much from the Mt. Diablo.

Taking the cost of pumping in Brooklyn, Philadelphia, Cincinnati, Louisville and Chicago, which, with St. Louis, contain the largest systems in the country, we find for the year 1875 the lowest price per million gallons raised one foot was at the Belmont Station in Philadelphia, where the cost was 7.85 cents. This general experience will probably be as satisfactory as any extended reasoning, and will we think justify the conclusion that the gross cost of pumping is not estimated too high in this report.

The price which is named by the promoters of this project is $10,860,000. For this sum it is proposed to establish a set of two pumps of capacity for 25 millions of gallons daily, with one pump in reserve; to construct an inlet tower in the river, with valves and conduit leading to a tank on the banks of the river, to hold 100 millions of gallons; a force main nine miles long, 54 inches diameter; a reservoir on the summit of Livermore Pass; a conduit 53 inches in diameter, leading from Livermore Pass to the city; and a city reservoir with a capacity of 250 millions of gallons.

It may be remarked that a conduit of 53 inches, having a fall of 3¼ feet per mile, will carry considerably more than 25 millions of gallons daily. It is however this quantity—25 millions of gallons daily—that is contemplated in the proposition. It may be supposed that the details of main, pipes, reservoirs, etc., which are not described with any special specifications, are entirely suitable to a city water supply. Inasmuch as the city reservoir is included in this proposition, we have only the street pipe service to provide for in addition, to place the project in working order.

Placing a street system, equivalent to the one now in operation, at a cost of $2,000,000, and allowing two years for the time necessary for the construction of the works, during which time we suppose the city bonds bearing six per cent. interest to be issued at an uniform rate, we have the following statement of the cost to the city of the works completed:

Amount of the proposition	$10,860,000
Add for street pipe system	2,000,000
Add interest at 6 per cent. for one year, half time of construction	771,600
Total	$13,631,600

which represents the cost of the completed works when ready for operation. The yearly interest on this sum at six per cent. is $817,896.

From this statement in connection with the cost of pumping as already determined, we are permitted to make the following table, which indicates the cost to the city of one thousand gallons, on the same basis which has been adopted for the other projects, and which omits the cost of management, extension of street pipes, and sinking fund. The cost of pumping 1,000 gallons to the height of Livermore Pass is taken as uniform for all deliveries. It will however be a fraction of a cent greater for all deliveries under 25 millions of gallons than is stated in the table.

TABLE A.

Millions of Gallons Delivered Daily.	Yearly Interest on $13,631,600 at six per cent.	Daily Interest.	Cost in Cents per 1,000 Galls.		
			Interest Account.	Pumping Account.	Total.
10	$817,896	$2,240.81	22.41	6.03	28.44
11	"	"	20.37	"	26.40
12	"	"	18.67	"	24.70
13	"	"	17.24	"	23.27
14	"	"	16.01	"	22.04
15	"	"	15.01	"	21.04
16	"	"	14.13	"	20.16
17	"	"	13.30	"	19.33
18	"	"	12.56	"	18.59
19	"	"	11.90	"	17.93
20	"	"	11.30	"	17.33
21	"	"	10.77	"	16.80
22	"	"	10.28	"	16.31
23	"	"	9.83	"	15.86
24	"	"	9.42	"	15 45
25	"	"	9.04	"	15.07

At this point new conduits and pumps will enter to increase the capital cost and interest account, and the price will for a period of years be more than 15.37 cents per thousand gallons.

The location of the headworks being but a few miles distant from the site selected for the San Joaquin and San Francisco Water Works, there cannot be much difference in the quality of the water taken from the two points

Both are now, since the channel has been opened at the head of Old River, situated on one of the main branches of the river, and both are subjected to the same influences. The remarks upon the quantity and quality of the water, made in connection with the project of the San Joaquin and San Francisco Water Works, apply to this case with equal propriety.

Instead of raising the water through the height of 740 feet by a single lift, the work may be done in two lifts, having a second station half way up the mountain. It can easily be shown that the single lift is the more economical method so far as pumping is concerned. The reduced strain on the pipes and pumps due to a division of the lift are however positive advantages, which would go far to justify a preference for the latter method.

CLEAR LAKE.

This source lies at an elevation of 1,300 feet in the Coast Range of mountains, nearly north from San Francisco, distant 80 miles.

The drainage area is mountainous in character and is estimated to be 500 square miles in extent, including the Lake which has an area of about 80 square miles. The rainfall at the Lake has been as low as 16¼ inches and as high as 66¾ inches in a year. It is presumable that the rainfall in the mountains exceeds that at the Lake.

The area of land in the drainage basin being 420 square miles, it will yield when one foot of water is drained off 87,680 millions of gallons. Let this one foot of drainage be supposed to result from a rainfall of two feet; the 80 square miles of the Lake will yield 33,440 millions of gallons. If we suppose this to be stored in the Lake, it will raise its surface something over seven feet. It is interesting to see how important a factor evaporation becomes in this case.

If we adopt the rule of five feet evaporation, we shall find that 83,600 millions of gallons will be lost in a season, which makes the available supply less than 40,000 millions of gallons. If we suppose a year to follow which gives only half the drainage we have supposed—namely, six inches from the land and one foot on the lake, a total of 60,000 millions—we shall have at the beginning of the season 100,000 millions, and at the end 20,000 millions, 80,000 millions being again lost by evaporation.

These remarks are intended to illustrate the disadvantage of reservoirs exposing a large surface to evaporation in our climate. They also show that it will be judicious to carry away the water from the lake in its season of abundance, and store it in a reservoir of less area and greater available depth. Such a reservoir exists on the adjoining stream to the south—Puta Creek, at Guenoc. With proper arrangements of this kind, Clear Lake can be made to furnish a large supply of water.

There are some difficulties, independent of those just mentioned, in the way of making the lake itself a large storage reservoir. The greater part of the fertile land about the lake lies just about the height of the natural high-water mark. If the water be raised to any considerable extent this land will be

overflowed. The rights of the owners would necessarily have to be acquired before a dam of any height could with propriety be placed at the outlet of the lake.

Cache Creek discharges the overflow of the lake into the Sacramento River. It runs, at the outlet, through a narrow gorge bounded on either side by high hills, and affords favorable sites for dams of any height likely to be desired.

A proposition was made to the Commissioners to furnish a supply from this source, but it is understood to have been withdrawn.

The quality of the water has been the subject of more discussion than the quantity. In the summer months appearances are decidedly unfavorable. The water has a temperature in summer as high as 75° on the surface and 72° at a depth of 50 feet. The surface of the lake is marked by numbers of floating bodies of fish during the summer months. The water holds in suspension a considerable volume of vegetable matter, and at times this imparts an appearance of flocculence. Where the depth is small there are large fields of tules, which are supposed to impart a slight peaty taste to the water. Immediately on the shores of the lake are borax springs and deposits of sulphur and cinnabar. Soda springs are found on the shores and in the bed of the lake.

These are what appear to be the objectionable features of the water and its surroundings, to which may be added the statements of parties living on the lake, that the water cannot be used for drinking purposes in the latter part of the summer, owing to its action on the human system. These objections are open to the observation of every visitor, and they naturally affect the judgment of observers in a very decided manner.

On the other hand, the water has been the object of chemical scrutiny and analysis, to a greater degree than any other source of supply. It has been repeatedly analyzed. By Louis Falkenau State Assayer in 1875, for the purposes of the previous investigation made in 1874 (see Appendix A); by Professor Chandler, of Columbia College, N. Y.; and by Henry G. Hanks, of this city, both at the request of the present Board of Commissioners; and in 1872, by Professor Price, of this city. These analyses are embodied in this Report. Professor Chandler states in a letter transmitting his analysis, that the character of the water is in every way satisfactory. He also says that the quantity of organic matter is not large, and is of no practical significance. Analyses have also been made of water taken a few miles below the lake, from Cache Creek, its only outlet.

The character of the drainage ground is such that a large population cannot be expected to live upon it. A little sewage contamination may be expected from villages on its shores.

Clear Lake is the nearest of the large or what may be called permanent sources of supply, and for this reason it ought to be less expensive than lines from the Sierra Nevada. The conduit however must cross the Bay, and this particular link needs demonstration before the project could require serious consideration.

The Commissioners visited the Lake, but no instrumental examinations

have been made by them. A line of survey was run in 1874 by way of Carquinez Straits and Oakland, and a report and estimate were made, which can be seen in the Municipal Reports for the year 1874-75.

Puta Creek lies to the south of Clear Lake, and drains a mountainous country of which Mt. St. Helena is the most prominent feature. There is a good site for a reservoir near Guenoc, with a storage capacity of 52,000 millions of gallons. Puta Creek itself has a considerable drainage area, estimated at 124 square miles, which is worthy of attention in this project. The stream has the usual Californian characteristics; that is, it is a torrent in heavy seasons, and dry or nearly so every summer.

It may be suggested that a line from this lake to the vicinity of Saucelito or to Lime Point offers some advantages, and is worthy of consideration in case the project should ever take a serious form.

The reports of analyses known to have been made are here reproduced as a matter of history. Professor Henry G. Hanks submitted to the Commissioners a detailed report, including both chemical and microscopic observations, which forms an appendix to this report.

ANALYSIS OF A SAMPLE OF WATER FROM CLEAR LAKE, BY PROF. C. F. CHANDLER, PH. D., SCHOOL OF MINES, COLUMBIA COLLEGE, N. Y.

	Parts in one U. S. Gallon of 231 cub. in.
Chloride of sodium	0.6794 grains.
Sulphate of potassa	0.2991 grains.
Sulphate of soda	0.0693 grains.
Carbonate of soda	0.7663 grains.
Nitrate of soda	trace.
Biborate of soda	trace.
Carbonate of lime	3.0616 grains.
Carbonate of magnesia	3.4045 grains.
Alumina and oxide of iron	0.1166 grains.
Silica	0.4374 grains.
Organic and volatile matter	0.6998 grains.
	9.5340 grains.
Organic matter in suspension	0.1166 grains.
Inorganic matter in suspension	0.4666 grains.
Hardness	4.08 degrees.

ANALYSIS OF A SAMPLE OF CLEAR LAKE WATER, TAKEN IN SEPTEMBER, 1872, BY PROF. THOS. PRICE.

	Per gallon of 231 cub. inches.
Carbonate of lime	2.554 grains.
Carbonate of magnesia	2.683 grains.
Carbonate of soda	0.728 grains.
Alumina and iron	0.012 grains.
Chloride of potassium	0.261 grains.
Sulphate of lime	0.341 grains.
Silica	0.464 grains.
Organic matter	1.970 grains.
	9.355 grains.

THE PENINSULA AND CALAVERAS SUPPLIES.

THE SPRING VALLEY SYSTEM.

This comparison of sources of supply would be incomplete without an inquiry into the resources, present and prospective, of the Spring Valley Works, which now supply the city. This inquiry ought to include the character and condition of the system, and the time and expense required to develop its resources to their maximum product.

The Spring Valley Water Company now derive all their supply from three sources, or if we speak in less detail we may regard the sources as two instead of three.

The nearest source is Lobos Creek, which drains a part of the area of the City and County of San Francisco. This source supplies about two millions of gallons daily, drained from about 2½ square miles of land. This quantity is conveyed by a conduit partly of wood and partly of masonry, 23,700 feet long, from the Creek to Black Point, where it is delivered at about the level of the city zero. It is there pumped into two reservoirs, one-third of it to the Lombard street reservoir on Russian Hill, which is 306 feet above the city base, and two-thirds to the Francisco street reservoir, which has an altitude of 139 feet. These reservoirs can contain 3,700,000 and 6,700,000 gallons respectively.

The supply from Lobos Creek is comparatively reliable. It results from the slow percolation of water through the sand, and is similar to that afforded by Laguna Merced. While it cannot be independent of the amount of rainfall, the circumstances under which it is afforded protect it in some degree from evaporation and hold it back, delivering it at a nearly regular rate. The sand hills may be considered in the light of a reservoir.

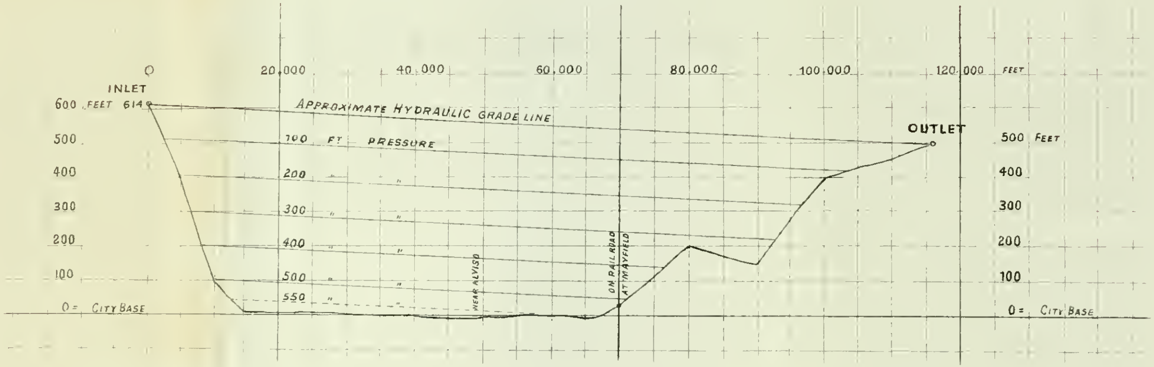
The last report of the President of the Spring Valley Company, made in June, 1876, states the daily consumption of the previous year to have been 12,300,000 gallons daily. Deducting two millions as coming from Lobos Creek, we have 10⅓ millions as the daily contribution made during that year from the second and remaining source of supply, which we now proceed to describe.

This lies in San Mateo County, partly within 12 miles of the city, and none of it so much as 20 miles distant. It consists of a drainage ground of 12½ square miles, made up in a way which will be presently noticed. The product of this drainage is stored in two reservoirs, which are known as the Pillarcitos and San Andreas.

PROFILE of the route of the IRON CONDUIT from CALAVERAS to a point near the head of CAÑADA RAYMUNDO.

Total length of Conduit 116,160 feet Total fall 114 feet

Scale 1 inch to 20,000 feet, &
1 inch to 400 feet.



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PILLARCITOS.

The Pillarcitos reservoir contains when full an available quantity of 1,080 millions of gallons. Its upper surface is 696 feet high. It is formed by an earthen dam built across the valley of the stream. The dam is 640 feet long on top, 26 feet wide on top, and 95 feet in height. The puddle pit is sunk below the base of the dam a distance of 46 feet. The interior slope of the dam is one vertical to 2¾ base nearly, while the exterior slope has a base of two and one-half to one vertical.

The reservoir is provided with two wasteweirs capable of passing over 800 millions of gallons daily. One of these wasteweirs is a tunnel through the easterly abutment of the dam. The other is built of wood. The capacity of waste is several times the largest increment yet received during a storm.

The dam was built about 13 years ago. Its interior slope has settled to a somewhat irregular form, which took place soon after it was constructed. Several years ago there was a leak in one end of the dam, which appears to have been due to unsound natural rock *in situ*, which had not been removed before construction. This leak, which threatened the stability of the dam, was remedied by sinking a shaft in the dam to the depth of 80 feet, removing the unsound rock and replacing it with clay. This operation was carried on when the reservoir was in a high stage. It was a delicate and dangerous work, but its success appears to have left the dam in good condition.

The supply from Pillarcitos is delivered in San Francisco to the Lake Honda distributing reservoir, at an altitude of 377 feet. This reservoir has a capacity of 33 millions of gallons. It, together with the Lombard-street reservoir before mentioned, supplies the high level distribution in the city. The conduit which conveys the water to Lake Honda is 83,820 feet in length, of which 67,450 feet are of 30-inch wrought iron pipe, 8,580 feet are wooden flume, and 7,790 feet of masonry, which is the lining of three tunnels. It can carry 12 millions of gallons per day.

The natural drainage basin tributary to Pillarcitos is four square miles. This has been increased by a flume of wood two miles long of 42 inches by 16 inches in cross section, which brings in the water from several small tributaries of Pillarcitos Creek, which join it below the reservoir. This side flume, as it is called, practically increases the drainage area one-fourth. Provision is made to carry the excess of water coming into the Pillarcitos to the San Andreas to the extent of 26 millions of gallons daily.

THE SAN ANDREAS.

The San Andreas reservoir lies about two miles northeast of the Pillarcitos. The top of the dam is 453 feet above city base. The dam is 640 feet long on top, and 25 feet wide. The slopes are 3 and 3½ to one. The top of the dam is 93 feet above the valley, and the puddle pit was sunk 47 feet below the base of the dam. The appearance of the dam is as favorable as could be wished.

There is no leakage, and the lines of the slopes are regular and apparently stable.

With 89 feet depth of water, this reservoir will contain 6,690 millions of gallons. The natural drainage basin has an area of four square miles. This is supplemented by auxiliary conduits, which pick up and discharge into the reservoirs such portion of the drainage of Lock's, Apanolio and San Mateo creeks as they can carry.

The Lock's Creek conduit is nearly 20 miles in length. It heads on the creek of this name, and has a capacity of 26 millions of gallons a day. The San Mateo Creek is conducted to the reservoir by a similar arrangement—7,190 feet of flume and pipe combined—which has a capacity of 18 millions of gallons per day; and the overflow of the Pillarcitos, already mentioned, is able to flow 26 millions of gallons a day. These areas, which are thus tapped and which contribute a part of their drainage water to San Andreas, comprise five or six square miles.

When the drainage is within the capacity of the auxiliary conduits, all of it is concentrated in San Andreas. This happens for a part of the winter and spring in ordinary years. During heavy storms a great part of the water is lost beyond recovery. In the summer these conduits are empty or nearly so. It is estimated by the Chief Engineer of the Company, that about half the drainage product is secured in this way to San Andreas, which is equivalent to the whole drainage of 2½ or 3 square miles. If this be admitted, the actual drainage area of San Andreas is 6½ or 7 square miles.

The city conduit leaves San Andreas by a tunnel driven through the mountain which bounds it on the east, and ends at College Hill reservoir, after traversing a distance of 70,080 feet, of which 63,999 are of 30-inch wrought iron pipe. The College Hill reservoir is 253 feet in height, and has a capacity of 15 millions of gallons. The conduit delivers 9 millions of gallons daily.

This is the system which has supplied San Francisco for a number of years; and the next point of inquiry concerns the value of this source of supply, estimated in the quantity of water it can be relied upon to supply to the city of San Francisco in years of variable production.

In order to have well in hand the meteorology of the peninsula of San Francisco, the following tables of rainfall in the city and at the reservoirs are given for the years covered by observation. The city observations are those kept by Thos. Tennent. The observations relating to the reservoirs are furnished from the records of the Spring Valley Company.

TABLE I.

RAINFALL IN SAN FRANCISCO (1849-1877), AS RECORDED BY THOS. TENNENT.

Seasons.	Quantity.	Days....	Seasons.	Quantity.	Days....	Seasons.	Quantity.	Days....	Seasons.	Quantity.	Days....
Jul. to Jul.	Inch.		Jul. to Jul.	Inch.		Jul. to Jul.	Inch.		Jul. to Jul.	Inch.	
1849-50 ..	33.10	53	1856-57....	19.81	61	1863-64....	10 08	37	1870-71....	14.10	46
1850-51....	7.40	44	1857-58....	21.88	56	1864-65....	24.73	59	1871-72....	34.71	79
1851-52....	18.44	48	1858-59....	22.22	68	1865-66....	22.93	69	1872-73....	18.02	49
1852-53....	35.26	70	1859-60....	22.27	73	1866-67....	34.92	71	1873-74....	23.98	85
1853-54....	23.87	79	1860-61 ...	19.72	70	1867-68....	38.84	78	1874-75....	18 40	45
1854-55....	23.68	67	1861-62...	49.27	83	1868-69....	21.35	58	1875-76....	26.01	69
1855-56....	21.66	54	1862-63....	13.62	52	1869-70....	19.31	47	1876-77*...	9.87	45

*To May 1.

TABLE II.

RAINFALL AT PILLARCITOS AND SAN ANDREAS, AS RECORDED BY THE SPRING VALLEY WATER COMPANY.

Pillarcitos.		San Andreas.	
Seasons.	Quantity.	Seasons.	Quantity.
July to July.	Inches.	July to July.	Inches.
1864-65	54.95		
1865-66	59.44		
1866-67	71.17		
1867-68	81.71	1868 { April, May, June }	5.33
1868-69	48.26	1868-69	38.57½
1869-70	48.21½	1869-70	35.70
1870-71	38.88½	1870-71	30.52
1871-72	78.28	1871-72	82.57
1872-73	42.19	1872-73	36.26
1873-74	50.31	1873-74	47.63
1874-75	44.04	1874-75	44.48
1875-76	66.93	1875-76	72.42
1876-77*	21.18	1876-77*	20.14

*Rainfall from July 1, 1876, to April 20, 1877.

Table III contains the water production actually drained from the ground and used. In some instances it was necessary to waste water for want of storage. The amount wasted was measured. The amount used or saved is understood to be subject to no decrease on account of evaporation, this loss being included in the last column.

TABLE III.

SHOWING THE ACTUAL PRODUCT UTILIZED OR WASTED IN SAN ANDREAS AND PILLARCITOS RESERVOIRS, FROM DATA SUPPLIED BY THE CHIEF ENGINEER OF S. V. W. CO.

Season.	Average Rainfall at San Andreas and Pillarcitos.	Area of Drainage Basin.	Millions of Gallons Produced Annually.	Perc'tage of rain drained from the ground....	Inches of Water drained off the ground into the reservoirs.....	Inches of Water due to ground and evaporation
	INCHES.	SQ. MILES.				
1870–71.........	34.70	9.00	1,195	22	7.7	27.00
1871–72.........	80.42	10.50	5,453	37	30.0	50.42
1872–73.........	39.22	12.50	2,938	34	13.4	25.80
1873–74.........	48.97	12.50	3,713	35	17.0	32.00
1874–75.........	44.64	12.50	2,619	27	12.0	32.64
1875–76...... ..	68.83	12.50	6,404	43	29.4	39.40
1876–77.........	20.00	12.50	300*	7	1.5	18.50

*The drainage for the winter of 1876–77 not accurately known.

The gauges are kept at the reservoirs. The drainage ground is as a rule several hundred feet higher than the gauges.

The inequalities of the product are very marked. The proportion of rainfall collected is as low as 22 per cent. in 1870–71, which was a year below the average, and runs up to 43 per cent. in 1875–76, when the fall was large. For three years following 1871, the proportion is quite uniform, being 37 per cent. in the first year and 35 in each of the others. In the year 1876–77 the rainfall was about 20 inches, and the product did not exceed 300 millions of gallons. An apparent anomaly is observable, when 39 inches give a product of 2,938 millions of gallons while 44 inches give only 2,619 millions. The rainfall of 1871–72 of 80 inches gives proportionately less than the year 1875–76 with a fall of 69 inches, which was not to be expected.

The drainage ground is generally timbered with a thick growth. The eastern side of San Andreas, however, has no timber.

These results go to indicate that no water product can be expected until a certain quantity of rain has fallen. This quantity is probably variable, and depends upon the dryness of the ground, its soil, slopes and vegetation, as well as upon the rate at which the rain falls.

While these results do not altogether harmonize with each other, and do not justify a statement of exact law of production, they afford valuable information. We learn that the percentage of production is, for this particular drainage, very much less than is usually assumed, and subject to great variations. Taken in connection with the tables of rainfall in a series of years, the table of production enables us to reach important conclusions.

We now approach the subject of averages as applied to water catchment, and it becomes necessary to state the circumstances under which averages of rainfall will lead to correct conclusions, and those under which they cannot be trusted. In England or in the eastern part of the United States, where the rainfall is not subject to absolute failure in any season, but does pass through a series of two or three years of reduced production, the rule is well established that averages must be based on the years of minimum rainfall alone, excluding the years of maximum production. In these cases the storage capacity is much less than in the cases we are discussing. Our circumstances demand larger storage, and in so doing they vary the law of catchment.

The extreme variability of the rainfall in different years is well known to all inhabitants of California. In San Francisco the extremes are 7.4 inches in 1850–51, and 49.27 inches in 1861–62. In the two years succeeding the flood of 1861–62, we have for one, 13.6 inches, and for the next, 10.08 inches. So that while the average fall is about 23 inches, the minimum is but one-third of the average, while the maximum is more than double the average, and more than six times the minimum. Again, in 1863–64 the fall is less than half the average, while the preceding year gave little more than half the average.

There is something like a law in the recurrence of dry years or of years below the average, which appear in pairs; instances of which are 1850–51 and 1851–52, 1862–63 and 1863–64, 1869–70 and 1870–71. The present year (1876–77) is one of the driest we have yet known, and if the analogy holds we may expect its successor to be below the average. Then again it happens that two wet years come in succession, as 1866–67 and 1867–68. It may also be observed that from 1853 to 1860 the fall is remarkably uniform, not varying much on either side of the average.

Attention will be given to the rainfall at the reservoirs, which is largely in excess of that registered in San Francisco, although subject to the same general law of variation.

Under these circumstances where one year gives us a supply of water much in excess of the consumption, and where perhaps the next two years each give much less than is required, it becomes indispensable to store in the season of abundance, in order to provide for the period of drought. This fact compels

a water supply system on the peninsula to be provided with reservoirs of suitable dimensions, proportioned to the demands of consumption, and bearing a relation to the extreme features of the meteorology of the climate. The dimensions of these reservoirs, it will be readily understood, must be much greater than would be necessary in other countries.

The rain is usually delivered from the clouds between November and May, soon after which time the streams become dry. The most favorable years give no water supply for half or nearly half the year. A year of drought gives no supply, so that it may happen that no drainage enters the reservoirs from March or April of one year to November or December of the next year, an interval of perhaps 600 days. During these two summers evaporation from the surface of the reservoirs is taking place at the rate of five feet a season. The case may possibly be even more unfavorable. There may be a second year of rainfall below the average, affording a very limited supply, as happened for instance in the years 1862–63 and 1863–64.

Under these conditions the production of these drainage basins must be treated by a law of averages. When the reservoir capacity is sufficient to store all the water which is drained from the land, it is possible to use the average rainfall of a series of years, and by applying a proper coëfficient deduce from it an average yearly product. But such a deduction is only possible when all the drainage water can be stored. A rainfall, which is too excessive to permit its drainage product to be stored, is no more valuable for water supply than a smaller precipitation which fills our reservoirs.

The size of reservoirs necessary to store the whole drainage waters may be illustrated by taking the years 1866–67 and 1867–68, where two flood seasons succeeded each other. The rainfall at Pillarcitos was nearly the same for these years and averaged 76 inches. We have no records at San Andreas for these years, but the proportion observed in succeeding years of heavy fall at these points, only two or three miles apart, may justify the assumption of about the same record for San Andreas.

We note in Table I for 1875–76 a storage of 6,400 millions of gallons for a rainfall of 69 inches Assuming that half of the excess over 69 inches reached the reservoirs, we ought to have in 1866–67, for a fall of 76 inches, a product of 7,200 millions of gallons. If the reservoirs contained 1,500 millions of gallons at the beginning of the season, the 7,200 millions of gallons added in say five months would make 8,700 millions of gallons. Allowing 1,500 millions of gallons for the consumption in the five months, the quantity at the end of the season in store would be 7,200 millions of gallons. The reservoirs are now full or nearly so in May. From May to December, say 200 days, the loss by consumption and evaporation being assumed at 2,000 millions of gallons, the next rainy season would be entered with 5,200 millions of gallons, a gain of 3,700 millions of gallons over the storage at the same time in the previous winter. The drainage of the second winter being the same as for the previous year, namely 7,200 millions of gallons, it is plain that a reservoir capacity of 12 or 13 thousand millions of gallons would be

necessary to accommodate the total drainage of two severe winters succeeding each other, and that with existing storage more than 4,000 millions of gallons would run to waste.

This calculation seems to show that in order to secure all the drainage on this basin in two succeeding heavy years, we must have a storage capacity largely in excess of that which exists, which is probably sufficient to contain more than the product of any single year thus far known, and nearly sufficient to hold the aggregated drainage of three years like 1874–75.

If we assume the reservoirs to be empty at the beginning of the first rainy season, instead of having 1,500 millions of gallons on hand, the case will be more favorable for the reservoirs by that amount, but the hypothesis is too hazardous to be admitted. It may be questioned whether even so small a storage as 1,500 millions of gallons on hand at the beginning of a season is a safe assumption under our peculiar climatic conditions, the vicissitudes of rainfall are so varied. In any case the reservoir capacity being sufficient to store all the drainage which our tables call for, it follows that the value of this drainage ground cannot be determined by averages of rainfall alone. We must then look to the actual production stored for our results.

If we take the average daily product for the years 1872–73, 1873–74 and 1874–75, as given in the tables, we find it to be 8,500,000 gallons.

The average amount stored for five years, beginning in 1872 and ending in 1877, counting the production of the present year as 300 millions of gallons, gives a daily supply of 8,750,000 gallons.

If next year prove to be the counterpart of 1870–71, the production will be about 1,600 millions of gallons. On this supposition, the average for the six years beginning in 1872–73 will be a daily supply of 8,000,000 gallons.

If we take the first two years in the table, and increase the production proportionately with the increase of area brought into use in the succeeding years—which gives 1,600 millions of gallons for 1870–71, and 6,500 millions of gallons for 1871–72—and then take the average of the succeeding years to 1878, giving 1878 a production of 1,600 millions of gallons, the average for the eight years is 8,800,000 gallons.

The above results may be tabulated as follow:

SERIES.	Number of Years.	Total Number of Days.	Total Production.	Average Daily Supply.
			Gallons.	Mill. Galls.
From 1872-73 to 1874-75......	3	1,095	9,270,000,000	8.50
From 1872-73 to 1876-77......	5	1,826	15,974,000,000	8.75
From 1872-73 to 1877-78......	6	2,191	17,574,000,000	8.00
From 1870-71 to 1877-78......	8	2,922	25,734,000,000	8.80

In the last series we have two years which give but four millions of gallons daily, and one which gives little or nothing. It is of course quite possible that next year, instead of giving 1,600 millions of gallons, may give nothing. On the other hand, we may have an average season and get seven or eight millions of gallons a day, or have an excessive year which will give fifteen or more millions of gallons. These different suppositions may be made at will, and the product per day can thereby be made to rise or fall within moderate limits, on either side of nine millions of gallons.

The annual report of the Spring Valley Company, made in June, 1876, states the consumption of the city for the year 1874–75 to have required daily 10,930,000 gallons, and in the year 1875–76, 12,320,000 gallons. The daily demand for the year 1876–77 is estimated to require 13,800,000 gallons. Allowing Lobos Creek to have furnished two millions of gallons daily, there was taken from the San Mateo reservoirs in the first year 8,930,000 gallons daily, in the second year 10,320,000 gallons daily, and the estimated draft for the present year was 11,800,000 gallons daily.

That the last two are unsafe drafts upon the reservoirs is shown by their present condition, which at the middle of April shows contents of about 2,500 millions of gallons, of which perhaps 300 millions of gallons will be lost by evaporation. If a draft of 11,800,000 of gallons a day is continued the total quantity will be exhausted in 185 days, and the next winter will be entered with empty reservoirs. If, however, the draft upon the reservoirs had been limited in the past three years to nine millions of gallons or thereabouts, there would now have been in store sufficient to relieve the city from some of the apprehension, with which we await the chances of the coming winter.

These considerations, based upon known facts which are derived from the records of the Spring Valley Company, point with tolerable directness and clearness to the conclusion that the value of the San Andreas and Pillarcitos basins—including their supplementary contributions from creeks in the vicinity—is a daily supply of about eight and a half or nine millions of gallons.

The character of the drainage ground supplying these reservoirs is in great part wooded and mountainous. There is but little cultivation of the ground within its limits, and the quality of the water is good. A part of the basin shows some limestone, which makes the water hard as compared with some of the supplies of the Sierra Nevada, but not to a degree to be exceptionable.

The supplementary conduits which pick up the water of Lock's and other creeks add, by the estimate of the Company, about one-third to the drainage area. These works must be regarded as temporary in character, and liable to be abandoned in case the necessity for them shall ever cease. Or, if they are kept up, it ought to be remembered that they are for the greater part of wood and subject to decay, and that they must always require more or less attention in the way of repair. It has already been remarked that a part of the conduit to the city is also wooden flume.

CRYSTAL SPRINGS RESERVOIR.

The Upper Crystal Springs is the name of the reservoir now in course of construction. The Lower Crystal Springs is a name applied to another site always contemplated in the future plans of the Spring Valley Company, the construction of which has not yet been undertaken.

The dam at the Upper Crystal Springs is now about 50 feet above the valley, and the reservoir can now store between three and four thousand millions of gallons. It had in store last April about 800 millions of gallons. It received little or no water last winter. The previous winter afforded a large drainage, and if the work had been advanced a year, the reservoir would now contain a supply of several thousand millions of gallons.

This fact illustrates the necessity of making a good start in dealing with averages, or in storing water. If calculation shows that a given increase of supply will be needed in a particular year, it is the part of prudence to secure the water in the year before; for in our uncertain climate it is not always possible to obtain water as we need it.

This reservoir is much lower than either the Pillarcitos or San Andreas. The floor of the outlet tunnel has an elevation of 220 feet. The dam is expected when completed to have a height of 82 feet, and to be 30 feet wide and 540 feet long on top. The top of the dam will then be 304 feet above city base. The water standing four feet below the top of the dam, the contents will be 9,400 millions of gallons. The slopes of the dam are 3½ and 3 base to one vertical.

This reservoir is situated in the Cañada Raymundo, five or six miles southeast of the San Andreas reservoir, and both are tributaries of San Mateo Creek. The drainage area is about six miles in length, measured from the southeast to the northwest, and its width varies from two to three miles. It contains about 15 square miles.

The rainfall has been kept by the Spring Valley Company for the past three years:

In 1874–75	33.48 inches.
In 1875–76	51.61 inches.
In 1876–77	16.00 inches, about.

The average in the San Andreas and Pillarcitos drainage basins for the same years was 44.64, 68.83 and 20.00 inches, showing the diminution of 25 per cent. in five or six miles.

The areas of the two basins which we have described are respectively 15 and 12.5 square miles. The rainfall is as three to four. The quantities of rain falling on these areas are therefore as 9 to 10, the Crystal Springs being the less. The approximate gaugings now to be mentioned indicate a co-efficient of production in the Crystal Springs larger than at San Andreas, although they hardly justify a positive conclusion.

In the winter of 1874-75, San Mateo Creek was gauged and delivered 4,638 millions of gallons from 23 square miles of basin, in which the gathering ground of Crystal Springs is included. This gave, for a rainfall of 33½ inches, nearly 12 inches drained off the ground, 21½ inches being absorbed and lost, and 36 per cent. saved. The co-efficient at San Andreas was 27 per cent. by Table III. In the year 1875-76 a fall of 51.6 inches drained from 15 square miles, by approximate measurement, 8,300 millions of gallons, equivalent to 31⅔ inches drained and 20 inches lost, 60 per cent. being saved. Forty-three per cent. was saved at San Andreas.

These sums would still have to be subjected to loss from evaporation in reservoirs, and the actual product utilized in consumption would therefore be less than the amounts given. In the first year the available product would have been about 2,700 millions of gallons; in the second, 7,500 millions of gallons; and in the third, nothing.

This reservoir has a capacity, assuming it at 9,400 millions of gallons, considerably in excess of any one year's drainage, although not enough to store the total product of two wet years succeeding each other. In this respect it resembles the other reservoirs. This want of storage prevents us from arriving at the water product by a system of averages of rainfall.

The probable value of the Cañada Raymundo reservoir is a daily supply of eight millions of gallons. There is no conduit connecting this reservoir with the city. The Spring Valley Company propose to lay a 42-inch wrought iron pipe to deliver about 18 millions of gallons daily at a height of 160 to 180 feet in South San Francisco, where a distributing reservoir will be constructed for the supply of the lower city service. This pipe will be about 20 miles in length.

The upper or Pillarcitos supply being reduced to small limits this summer, the Company is now establishing pumps to raise the water in this reservoir to the Pillarcitos conduit, a height of more than 400 feet. Pumping is the only way by which this water can be made available until the conduit to the city is laid.

The actual drainage basin of the Upper Crystal Springs may be increased by means similar to those used for the upper reservoir. A part of the drainage of San Mateo Creek that now runs to waste can be conducted to the reservoir, and a tunnel can bring in part of the drainage of a small creek west of the Cañada Raymundo.

The character of the drainage ground of the Crystal Springs reservoir is essentially the same as that of San Andreas. The mountains which bound it on the west are timbered, and the eastern slopes are bare.

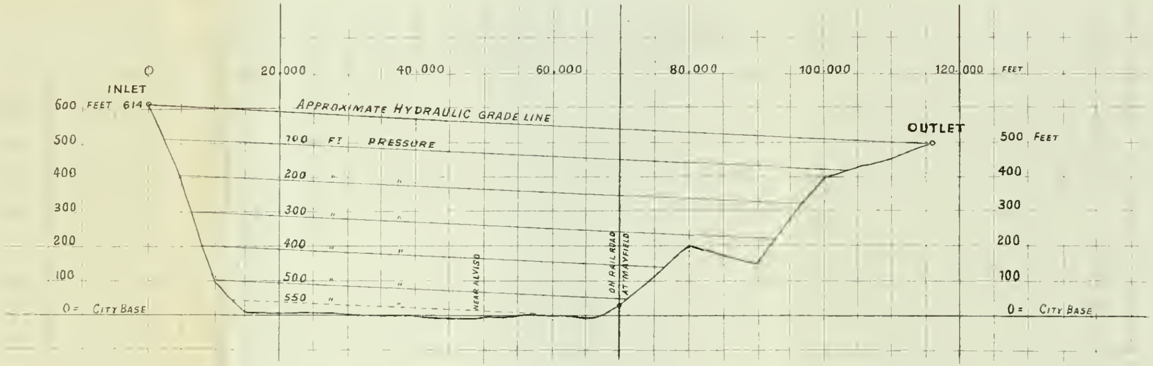
It will be noticed that the reservoir, when completed, will have a capacity of more than three times the product of an average year, as 1874-75 may be called, bearing nearly the same relation to the drainage ground as the upper system of reservoirs. The latter have a reservoir capacity of 80 millions of cubic feet for one square mile of drainage area. The Crystal Springs reser-

PROFILE of the route of the IRON CONDUIT from CALAVERAS to a point near the head of CAÑADA RAYMUNDO.

Total length of Conduit 116,160 feet. Total fall 114 feet

Scale 1 inch to 20000 feet, &

1 inch to 400 feet.



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voir has 83 millions of cubic feet storage for one square mile of area, which is 129,700 cubic feet per acre of drainage ground.

These quantities are largely in excess of those existing in other cities. Liverpool has 48,500 feet, Loch Katrine (Glasgow) has 30,000, and Dublin 25,500. This statement illustrates the peculiar necessities which are forced upon us by our climatic conditions.

It has been remarked that the dam is yet to be raised 32 feet. This can readily be done in one season. The dam is made of excellent material found in the vicinity, and the character of its construction is worthy of all commendation. Each detail of the work is attended to with care, and no expense seems to be spared to insure efficiency and safety. The clay puddle is carried in this case to a depth of 90 feet below the bed of the valley, at which depth the foundation is understood to be in clay, no rock being found at that depth.

THE CALAVERAS.

The system which has been described comprises all the resources of the Spring Valley Company, either wholly or partially developed at the present time. When the consumption of the city shall have reached the limit of the daily product from this drainage ground of 27 or 28 square miles, the Company must be prepared with an additional supply. This supply may come either from the western slope of the coast mountains of the Peninsula which are drained by the Pescadero, San Gregorio and other small streams, or it may be derived from the Calaveras. The latter point is the one contemplated in the plans of the Spring Valley Company as first to be developed, and for that reason it will now receive attention.

The Calaveras is a tributary of Alameda Creek which it joins at Suñol Station. It runs in a north-westerly direction, and is separated from the Santa Clara Valley by a range of hills varying in height from one to two thousand feet.

The drainage area above the reservoir site is about 25 miles in length, with an irregular depth of three miles in some places and seven in others. By actual survey made by Mr. Scowden, the area of the drainage basin is 101 square miles. In this basin is Mount Hamilton, a conspicuous feature in the topography of the country. It has an altitude of 4,400 feet. This area is almost entirely uninhabited, a few persons being engaged in the pasturage of sheep and cattle. Above the reservoir site there is little or no cultivation. The country is extremely rough. The creeks run at the bottom of steep defiles, and are in many places almost inaccessible. There are no roads through the upper and main part of the drainage basin. The hills are timbered in some places sparsely with groves of oak, and in others thickly with pine, oak and shrubs.

The following notes in regard to the geology of the district are compiled from the report of Professor Whitney:

The geological formation of the Calaveras Cañon may be characterized as

tertiary, and is composed largely of metamorphic calcareous sandstone, the strata dipping generally to the northeast at a high angle, sometimes nearly vertical The ridge due west of Mt. Hamilton however, forming some eight miles of the watershed line, Mr. Whitney classifies as highly metamorphic mica slate. Mount Hamilton he speaks of as being largely composed of metamorphic sandstone very much broken and distorted, indicating great local disturbances.

Further down the cañon or east of Milpitas, and forming the westerly boundary of the site of the proposed reservoir, the hills are spoken of as being "made up of strata of metamorphic sandstone very much broken and "irregular, standing vertically or having a high dip to the northeast, rarely "in the opposite direction. Tertiary fossils were obtained in considerable "quantity, but usually in a very poor state for determination, owing to the "hardness of the rock in which they were imbedded."

Still further down the cañon the general character of the surface rock continues about the same until we reach the neighborhood of Mission San José. The same author states in reference to this locality: "Back of San José "Mission rise hills of unaltered sandstone with very abrupt sides in which "the strata dip to the northeast."

Just above the dam site the defiles of the hills open into an expanse of valley, which is the proposed reservoir. The fall of the valley is considerable, being about 70 feet to the mile, which makes a high dam necessary in order to store much water. In other respects the site is favorable. The dam sites are at the gorge, where the mountains on either side form the abutments, with slopes of one-half or less. The bed of the valley does not here exceed 150 feet in width. The reservoir itself is not the valley of the Calaveras proper, which enters near the middle of the storage basin.

The height of the creek at the site of the dam proposed by Mr. Scowden is 563 feet. A sufficiently high dam will give good opportunity to deliver the water into San Andreas reservoir, and some may even be discharged into Lake Honda reservoir in the city and contribute to the high service supply. Excavations have been made in a half dozen places on the site of the proposed masonry dam to the underlying rock. These expose serpentine.

Our information in regard to rainfall is, as at Crystal Springs, confined to the past three years. It is almost needless to remark that a much longer series of observations is desirable, in order to give us exact ideas as to the quantity of water which we can confidently expect from this drainage basin. The reservoir capacity, which we have already seen to be an essential and determining element in the problem, and which is supposed to be known, at least approximately, relieves us from a great part of the difficulty which might be expected to result from deficient observations of rainfall. In addition to the rainfall for these three years we have the approximate gauging of the Calaveras Creek as kept for 120 days by Mr. Scowden, and since in a rude way by an employé of the Spring Valley Company.

The rainfall was observed during the year 1874–75 from October 20 to March

28, and found to be 17.04 inches. The rainfall of the season subsequent to March 28 was 2.46 inches, making a total of 19.50 inches. The observations for 1875–76 were kept by an observer of the Spring Valley Company, and the amount was 40.5 inches. In the present season the same observer kept observations at the reservoir site, which gave a total of 12.5 inches. An observer was placed in the upper drainage ground by the Commissioners in the present season, who kept observations at five different points from January 1st to March 13. The season was very dry, and it was not thought necessary to prolong observations later than March 13.

The results of these observations are shown in the following table:

	Station 1.	Station 2.	Station 3.	Station 4.	Station 5.	Station 6
1877.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
January..........	6.37	5.56	5.53	8.75	6.22	4.07
February.........	.34	.36	.47	.43	.33	.34
March (to 13th)..	1.20	1.11	.93	.86	.89	.98
	7.91	7.03	6.93	10.04	7.44	5.39

The stations were on Mt. Hamilton and on each side of it. The positions and altitudes are as follows:

No. 1.—In valley of Smith's Creek at western foot of Mt. Hamilton. Altitude 1,950 feet.

No. 2.—Western flank of Mt. Hamilton. Altitude 3,000 feet.

No. 3.—Eastern flank of Mt. Hamilton. Altitude 3,450 feet.

No. 4.—Isabel Valley at the eastern foot of Mt. Hamilton. Altitude 2,250 feet.

No. 5.—On flank of mountain on east side of Calaveras Creek, and four miles north of Mt. Hamilton. Altitude 2,200 feet.

No. 6.—On the western flank of the western mountains bounding Calaveras, therefore not in Calaveras Valley but to the west of it. Altitude 1450 feet.

The observations show very clearly that the rainfall in the Calaveras basin is in excess of that on the western flank facing Santa Clara. They also appear to indicate no greater fall on the mountains than in the valley. On the contrary, Isabel Valley gives a greater fall than any point above it.

The corresponding observations at the reservoir site for the month of January were 6.5 inches, for February two-thirds of an inch, and from the 1st to the middle of March three-fourths of an inch, being a total of 7.92 inches.

The gaugings of the creek at the reservoir site are as follows:

For 120 days, from Dec. 2, 1874, to March 31, 1875, by Mr. Scowden, 12,347,817,000 gallons. For the remainder of this season, as observed by the

Spring Valley Co., 1,116 millions of gallons; a total for the year 1874–75 of 13,464 millions of gallons. For the year 1875–76, by Spring Valley measurement, 58,230 millions of gallons. For the year 1876–77 about 2,800 millions of gallons. The gauging for 1875–76 can only be considered approximate.

It may be said in further explanation that the Calaveras Creek in average, and perhaps in all years dwindles to little or nothing in the fall months. During such winters as that of 1875–76 it becomes a torrent and in the gorge selected for the dam site rises to a height of 15 or more feet. It rarely maintains any such flowage but for a few hours. Its greatest flood is supposed to come with a warm rain, which takes off the snow which is often deposited on the top and flanks of Mt. Hamilton. On the 1st June, 1876, the stream carried quite 15 millions of gallons daily. On 5th April, 1877, it was found to flow but six millions of gallons.

The project proposed by Mr. Scowden for bringing these waters to the service of the city contemplates a storage of 40,000 millions of gallons in a single reservoir, of which 4,500 millions must be unavailable, being below the outlet tunnel. The remaining 35,500 millions of gallons represent the available storage, which requires a dam 208 feet in height.

If this be the only reservoir, it appears at once that the drainage of 1875–76 which amounted to 58,000 millions of gallons would have filled this reservoir supposed empty at the beginning of the season, and 18,000 millions of gallons would have run to waste. This quantity of water might quite as well have remained in the clouds or never been evaporated from the Pacific Ocean, so far as any benefit to the water supply is concerned. This simple statement proves at once how fallacious is the whole argument of averages unless there is provided storage for all the water that falls.

We see what storage capacity was required to contain the drainage of 1875–76. Now let us suppose to occur again what happened in 1866–67 and 1867–68, namely, that a winter giving 58,000 millions of gallons is succeeded by another winter giving 58,000 millions of gallons. Where are we to put the surplus of 20 or 30 or more thousand millions of gallons due to this year? It must go where the last surplus went—back to the sea.

At Crystal Springs and at San Andreas the reservoir capacity is equal to any supposed one year's drainage, and perhaps it exceeds any that we may have. To place Calaveras on the same line of argument which has been applied to these other basins we must provide a storage of something like 58,000 millions of gallons. This storage is probably not to be thought of. The maximum drainage of 100 square miles has never been impounded, and probably never will be impounded.

It follows then without any possibility of question that any averages that may be struck on the Calaveras must take for the maximum element, not a percentage of the rainfall, nor even the quantity of water which drains off the ground in a flood season, but that fractional portion of it which can be stored in our reservoirs.

The plan which is proposed to his company by the Engineer of the Spring

Valley Company, is to build a masonry dam 183 feet high at a point about 1,000 feet lower on the creek than Mr. Scowden's dam site. The creek falls six feet in this interval, so that the storage capacity afforded by a dam 183 feet high at the lower site will be about the same as that afforded by a dam 178 feet high at Mr. Scowden's site. When the water stands within five feet of the top of the dam the contents will be about 26,000 millions of gallons, of which 1,000 millions of gallons will be unavailable, being below the floor of the outlet tunnel.

The floor of the outlet tunnel starts at reference 626, sixty-eight feet above the base of the dam. The tunnel is to be cylindrical, eight feet diameter, lined with brick masonry, falling one foot in a thousand. At the inner end of the tunnel an inlet tower will be constructed with wire screens and valves arranged to draw water from any desired depth. At a suitable point on the line of the tunnel a gate shaft is proposed, with the necessary gates for regulating the discharge of water. The tunnel line is by survey 11,700 feet in length, and the floor at the western end, where it will connect with the syphon which is to cross the Santa Clara Valley, will have an elevation of 614 feet. The tunnel is proportioned to carry about 150 millions of gallons daily.

The syphon starts at the end of the tunnel and terminates about two miles from the head of the Crystal Springs drainage basin. The profile of the ground is in great part from actual survey, and the pressures on the conduit are shown in the accompanying diagram. The route of the conduit is by Milpitas, Alviso and Menlo Park. The size of this conduit is yet to be determined, whether to carry 30 or 40 millions of gallons daily. The length of the conduit is 22 miles, and the fall on the whole length is 110 feet. The outlet will therefore be at reference 504.

The iron conduit will discharge into a canal which will carry the water about two miles and deliver what may be required into the Cañada Raymundo reservoir, and then follow along the side hills on the eastern side of the Cañada until it reaches the point where the valley of San Mateo Creek intersects the line. The water will be carried across this valley by one or more syphons, which will discharge into the canal which resumes its course towards the San Andreas reservoir. The canal will be proportioned at first to carry 50 millions of gallons daily, to be increased afterwards to 1,000 millions or to such a delivery as may be required. The canal and syphon will be 22 miles long, as nearly as known. The canal has a fall of two feet to the mile. The total fall from the end of the iron conduit to San Andreas will be 44 feet, four feet being allowed for the syphon.

The canal is to be excavated in the solid ground and be lined with brick laid in mortar, four inches on the bottom and eight inches on the slopes. Its proposed dimensions are six feet wide on bottom, 13 feet on top, depth 2½ feet. The area of section will be nearly doubled by an additional depth of one foot. The line of the canal has not been surveyed in detail, but the levels have been ascertained, and the other information in regard to it is such that it can be estimated upon with comparative closeness. It should be re-

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marked that the summit of the drainage basin of Crystal Springs, on the canal line, is something like 60 feet too high to permit the canal to cross, and hence a tunnel 1,200 to 1,500 feet in length will be necessary to permit the entrance of the Calaveras water into the Cañada Raymundo.

The cost of carrying out this project has been estimated with as much care as possible. The largest item is the dam. Its contents for the proposed site have been calculated on the strongest type of profile recommended by the best authorities, and are found to amount to about 200,000 cubic yards. The stone in the vicinity of the dam site is not suitable for a construction of this kind, unless concrete be used, material for which is found in the valley, having been washed down by the stream. Using rubble masonry, it would probably be necessary to go to a considerable distance for stone, perhaps to the foot-hills quarries of the Sierra, and bring it by a railroad to the site. This would require a road eight or ten miles in length, to be built from Suñol Station to the dam site. If concrete should be selected for the material it might be laid for 12 to 14 dollars a yard. It is preferred to assume the cost at $17.50, including in this all incidental operations.

ESTIMATE OF COST.

Dam—200,000 yards, at $17.50 per yard	$3,500,000
Outlet tunnel—11,700 feet long, 8,400 feet of which must be worked from two heads, with shaft, inlet tunnel and gates complete	650,000
Total cost of canal—20 miles, at $20,000 per mile	400,000
Wrought iron conduit—60-inch diameter, 22 miles in length	2,286,200
Total cost	$6,836,200

The lengths of the dam on the top and bottom are respectively 750 feet and 150 feet.

It must be remarked that this scale of work is proposed by the Spring Valley Company, upon the hypothesis that eventually a supply will be afforded by the Calaveras, the Arroyo Honda and the Arroyo Valle, of something like 150 millions of gallons a day. It is quite impossible to say, in the present state of our knowledge, what may be expected from the last named two drainage basins which have areas of 40 and 110 square miles respectively; but it is certainty itself that the available supply cannot be ascertained by taking the mean of rainfall, even if it is known; but the yield must be measured by the reservoir capacity. In regard to this point we now know nothing, and until we are informed it is quite useless to speculate on the subject. We are therefore compelled to confine our attention to Calaveras in regard to which we have accurate knowledge, or if we can go outside, it is only to secure what water can be taken from the streams as they flow in the Arroyo Honda or elsewhere. In this way something may be done by means similar to those which increase the effective area of San Andreas, but this is but a fractional and probably a very small part of the flowage of the outside districts.

The capacity of storage afforded by a dam 183 feet high at the proposed

site is 25,000 millions of gallons. Now if this dam had been ready for service in the fall of 1874, it would have contained, after receiving the year's drainage, 13,464 millions of gallons. The outlet works and pipe being in order, we may suppose a draft of 30 millions of gallons a day, beginning in the fall of 1874, to have been drawn off for a year for consumption in San Francisco—taking away 11,000 millions of gallons, 1,000 millions being unavailable by reason of its level, there would have remained in the reservoir available 1,464 millions of gallons, a quantity not much more than enough to supply the year's evaporation.

The reservoir would then have been practically empty at the beginning of the flood season of 1875–76, which brought down 58,000 millions of gallons. Of this the reservoir would have saved 25,000 millions of gallons, plus the amount carried away by the conduit during the rainy season, which we may fairly take at 4,000 millions of gallons, being 30 millions of gallons for 133 days.

This would bring us to April 1st, 1876, when we have the reservoir full—that is, it contains 25,000 millions of gallons. By December, 1876, we will have taken out 240 days' supply—7,200 millions of gallons directly—and the sun will have taken out hard on to 2,000 millions of gallons, the increased evaporation being due to the increase of area of water surface over that exposed in the year before. Let us call the gross amount of consumption and evaporation 9,000 millions of gallons.

Then on December 1st, 1876, our reservoir will have in store 16,000 millions of gallons. The year 1876–77 afforded say 2,800 millions of gallons. Then crediting it all on December 1st, 1876, we get up to 18,800 millions of gallons. From this time to December 1st, 1877, we take out and evaporate 12,500 millions of gallons, still using 30 millions of gallons a day. Hence on December 1st, 1877, we have in store 6,300 millions of gallons.

Now we may make conjectures. We have thus far proceeded on facts, real or approximate. Let us suppose the year 1877–78 to be the same as the year 1876–77, affording nearly 3,000 millions of gallons. Adding this to our reserve we enter the year with 9,300 millions of gallons. A draft of 30 millions of gallons daily with evaporation will take all of this and require 3,000 millions of gallons more, so that in December, 1878, we start again with an empty reservoir.

We have never had more than two dry years in sucession, and we may now suppose ourselves to start on a series of average years like those of 1872 and the two following.

The first of these years would have given us, as 1874–75 did, about 13,500 millions of gallons, being about 19 inches rainfall. The second year giving about 25 inches of rain would have yielded perhaps 20,000 millions of gallons, and the third year would have done about as well, so that we would go along very well for a 30 millions of gallons draft, with something to spare.

While what may be called average years give us easily 30 millions of gallons

daily, whenever we apply the test of two dry winters succeeding each other we are liable to fall short of 30 millions.

Objection may be made to the height of this dam, namely 183 feet. It is probably higher than any dam in the world. The Furens dam in France is 160 feet in height. As the height is increased the width of the base and the contents of masonry, and consequently the cost of construction, increase very rapidly. The pressures on the masonry at different depths, due to its own weight and to the thrust of the water, are all subject to calculation and may be ascertained with exactness. The strength and weight of the material used in construction admit of exact measurement. When these facts are known as they may be known, and safe margins of strength and stability are adopted, the profile of the dam becomes a matter of calculation, and is entitled to the same measure of confidence that is given to other engineering constructions which result from calculation. This confidence however is entirely consistent with the prudent feeling which would prefer to store so large a quantity of water in two reservoirs rather than in one.

Mr. Scowden in his report makes allusion to a reservoir site in the Isabel Valley lying to the east of Mt. Hamilton, which can store 9,000 millions of gallons.

If we reduce the height of the dam at the Calaveras site from 183 to 163 feet the effective storage will be reduced from 25,000 millions to 17,300 millions of gallons, the reduction being rather less than the storage capacity of the Isabel Valley reservoir. If this latter reservoir prove practicable in every sense, this arrangement of storing in two reservoirs as compared with one is to be preferred, even at the extra loss which will occur by evaporation.

The contents of a masonry dam 163 feet high at the Calaveras site will be about 150,000 cubic yards, a reduction of 50,000, as compared with the contents of a dam 183 feet high. At the estimate of $17.50 per cubic yard, the saving due to this reduction will be $885,000. This sum ought to do more than build the Isabel reservoir.

Under either of these arrangements the product of the Calaveras watershed cannot prudently be estimated to amount to more than 30 millions of gallons daily. If additional storage can be provided the daily average supply will be ncreased proportionately.

It is possible to make a large storage reservoir at the Lower Crystal Springs site. The total drainage area of this reservoir, not now paying tribute to the neighboring series of reservoirs, is about eight square miles, comprising a part of the areas of San Andreas and San Mateo creeks. This area will supply, in maximum years like 1875–76, about 5,000 million of gallons, and in average years 1,500 or 1,600 millions of gallons. The storage capacity given by a dam raising the water to the 300-foot curve, measured from the city base, is, as near as can be estimated from the imperfect maps which have been consulted, about 37,000 millions of gallons. Allowing 8,000 millions of gallons storage to the Cañada Raymundo proper, there will remain something like 29,000 millions of gallons for the lower reservoir, which is about 23 or 24

thousand millions of gallons in excess of the requirements of its own natural flood drainage. It will take a dam about 165 feet in height above the valley to give this storage. This reservoir must take care of the water that is derived from the Pescadero and the adjoining streams. Any extra storage remaining over can be devoted to the Calaveras, or the whole may be applied to the Calaveras, leaving the western coast supplies out of the question. If this reservoir and that at the Calaveras had been ready in 1875-76, 50,000 millions of gallons could have been stored in the two reservoirs combined.

But in order to save the Calaveras water we must have had conduit capacity to carry it off as it passed the Calaveras dam site. Let us suppose the water to have passed in such a way that 150 millions of gallons a day could have been afforded to our conduits for every day from November 1st, 1875, to April 1st, 1876, a period of 150 days. We could have carried away in that time 22,500 millions of gallons. Three conduits of 40 millions each and one of 30 millions would have been required, the cost of which is about 8½ millions of dollars, at present prices of iron. These conduits being in operation might have saved 47,500 millions of gallons instead of 25,000 millions as before supposed, and the conduits would have been in service five months. In years which give less than 25,000 millions of gallons in the Calaveras, these extra conduits will have no work to do unless it be preferred to carry the water to Crystal Springs in order to save the excessive evaporation of the Calaveras, in which case they would be employed to do this. And even in flood years they will be idle the greater part of the time.

We have here again reproduced in conduit capacity what we have seen to be necessary in the matter of reservoirs—namely, a provision of capacity regulated for flood years, to remain idle in ordinary years. It certainly appears questionable, in the present state of our knowledge, whether this arrangement of conduits would be judicious. If we were as fully informed of the yield of Calaveras for the past eight or ten years as we are of the San Andreas drainage ground, it might be practicable to trace up, year by year, the operations of any supposed number of conduits and finally arrive at something like the yield that could be depended upon, and the cost of securing and storing it; but at present to attempt such a course of reasoning, in the absence of well-authenticated facts, would involve us in such a maze of conjectures and assumptions as to render our conclusions utterly unworthy of confidence.

The only reasonable and practicable conclusion which now seems justifiable is that which we have indicated, which however should be regarded as rather in excess of the quantity to be expected than below it. That conclusion is that the average supply to be confidently and safely expected from Calaveras is 30 millions of gallons daily. This amount, it may be repeated, may possibly be increased by further storage in the drainage basin of the Arroyo Honda and Arroyo Valle, but our information is so limited that it would not be safe to lay much stress upon future possibilities.

It remains to state the probable expense of making the Calaveras avail-

able. If we proceed on the basis of the conclusions which we have reached, it will be apparent that the scale of works outlined for the future by the Spring Valley Company is entirely too large for the requirements of the case, as they appear to us.

In the Spring Valley plans the outlet tunnel through the mountains west of Calaveras, and the canal around the head of Crystal Springs are proportioned to carry 150 millions of gallons. The tunnel alone will have to be completed in its full dimensions. The canal can be made at first to carry 50 millions of gallons per day, and afterwards its capacity be increased as occasion requires. Although the probability is that a canal of this capacity will not be required, yet the saving in cost due to a reduction of the capacity of the canal will be insignificant, and we may retain the canal as originally projected, for 50 millions of gallons daily.

The tunnel may be reduced to a convenient working size—say six feet instead of eight feet diameter—which would reduce the cost to about two-thirds of the original estimate.

A dam 123 feet high will impound about 7,000 millions of gallons and will contain less than one-third of the masonry required for a dam 183 feet high. A dam 133 feet high will store over 9,000 millions of gallons and will contain two-fifths of the masonry required for a dam 183 feet feet in height.

These facts suggest the probable practicability of extending the cost of the dam over a number of years. Having built it to a height of 123 feet we at once begin to have the benefit of its storage. By additions in successive years as needed, the dam would gradually attain its final and full proportions.

In order to carry out this construction the lower side of the dam would be left in blocks or steps, affording the opportunity of making a good bond uniting the new with the old masonry. In this way the work could be carried on and bring some results in the way of supply each year after the first two or three, and be completed only when the city demands have risen to the ultimate supply. It will require two years to build the tunnel and canal, and in three years it would be possible to get some results from Calaveras which would grow as just stated.

The cost of delivering 30 millions of gallons from the Calaveras into San Andreas would be:

For Storage	$3,500,000
For Outlet Tunnel and Canal	800,000
For Iron Conduit, 50 inch diameter, 22 miles long	1,587,653
	$5,887,653
Add 10 per cent for contingencies	588,765
	$6,476,418
Add interest for two years on cost of dam and tunnel and canal	500,000
Total	$6,976,418

The cost of the masonry dam is very much in excess of an earthen dam impounding the same quantity of water.

There are and will be radical differences of opinion regarding the construction of this dam, which is really the key and essence of the Calaveras supply.

Engineering literature has a good deal to say upon the two sides, whether our dams ought to be of stone or earth. It is preferred in this report to keep within the limits of well established experience, so far as it is known. The day may come when an earthen dam 200 or more feet high shall be built, and a long subsequent experience may perhaps prove that it was a reasonable and proper thing to have done. The soundest possible achievements of engineering, whether in dams or in other constructions, are however to be anticipated in a kind of structure which admits of calculation and in which the well established laws of strength and resistance of materials permit deductions, which shall prove within defined limits the position of the line which divides the safe from the unsafe.

These conditions appear to the undersigned to be wanting in earth, and if they are so wanting, it follows that predictions resulting from calculations are impossible in earthen dams. What we know of earthen dams we know because we have seen it, and if the question be asked, whether an earthen dam of any given height and material is safe, we can only be certain when we have seen or known a dam of that height and material which experience has proved to be safe. On the other hand, the elements of weight, adhesion, friction and pressure, which are ascertainable and definite quantities, permit us to establish the extent and direction of the forces which affect, either favorably or unfavorably, the stability of a stone dam, and reduce the proposition to a problem in physics, in which the good judgment of the engineer determines the margin of safety by which the practical shall exceed the theoretical. If this reasoning is sound it follows that a question as to the safety of a stone dam can be answered, not only by experience but also by well-established principles of construction.

Passing from speculation to fact, the highest dam of which we have a record is the masonry dam at Furens, which is 160 feet in height. The highest earth dam does not much exceed one hundred feet. If then we are to be governed by the experience of others, and do not permit ourselves to enter upon untried fields and assume risks the magnitude of which cannot be estimated by any known laws, we must confine our dams of earth to a height of about 100 feet.

It is sometimes said that nature has dams of much greater height than any we propose, which have stood the pressure of ages. This is true, and if we could hope to imitate nature in the scale of her dams, discussion would be unnecessary. Take for instance Lake Tahoe, which is said to be 1,500 feet deep. The crest of the dam is the bed of the Truckee River, as it leaves the lake. The river falls 60 or 70 feet to the mile, so that it reaches the level of the bottom of Lake Tahoe in 20 or 25 miles. This distance is the base of the granite dam, 1,500 feet in height, of Lake Tahoe.

The foundations at San Andreas, Pillarcitos and Cañada Raymundo are all in clay. Under these circumstances earthen dams were the only constructions open for adoption. It is proper to remark that the construction of the

Spring Valley dams is such as to entitle them to every confidence. Every precaution in the selection, preparation and placing of the material used in the dam is taken with care and intelligence.

We may at the close of this review of the Spring Valley resources south of San Francisco, now in action or contemplated within the next few years, gather the conclusions in compact form.

The maximum daily resources which can be counted upon for a series of years are:

From the San Mateo Drainage Basins	17 million gallons.
From Calaveras	30 " "
From Lobos Creek	2 " "
Total	49 million gallons.

Somewhere between 40 and 50 millions of gallons will be found the reasonable product of these reservoirs and drainage basins—never so low as 40 and never so high as 50—under the hypothesis that seasons will follow each other in the future as they have occurred in the known past.

Bringing forward the cost of the Calaveras works, which we have found to be	$6,976,418
we must add, for the completion of the Crystal Springs Dam—32 feet in height—80,000 yards, at 50 cents	40,000
and for the conduit from Crystal Springs to the city and reservoir in San Francisco	1,000,000
and we have a total of	$8,016,418

as the sum which must be added to the purchase price of Spring Valley as the cost of making the described resources available at the San Mateo County reservoirs.

If the conduits across the Santa Clara Valley were laid, and the canal connecting with Crystal Springs and San Andreas built, it would be possible to get a supply of water from the Calaveras before the outlet tunnel is completed. This would be a temporary device and would consist of a wooden flume starting on the Calaveras at a height of about 1,000 feet, with such a fall as would carry the water over the summit of the hill which overlooks the Santa Clara Valley. This height is something over 900 feet. From this point the water could readily be delivered to the head of the pipe 300 feet below. Such a flume could be built for something like $150,000, and in connection with the Isabel Valley reservoir could maintain a certain supply in advance of the construction of the lower dam. This is a possible project, which might or might not prove to be advisable.

The Isabel Valley reservoir has a drainage area of 25 or 30 square miles, comprising the eastern and southern slopes of Mt. Hamilton. All accurate information that exists is derived from the surveys of Mr. Dyer. It appears from these that a storage of 9,800 millions of gallons is possible with a dam

154 feet high. It appears from the profile that another site near by will give a storage not very much less, with a dam of 124 feet high, and about 400 feet long on top. It will require nearly two feet drained off the land to fill this storage capacity. A dam 105 feet high will give between five and six thousand millions of gallons storage. This reservoir is an important feature in the Calaveras system, and whatever storage can be effected here is so much saved in the height of the dam below.

The best reservoir site for the waters of the Calaveras is at Suñol, where a dam across Alameda Creek would be able to store the drainage of quite five hundred square miles. The height of the ground at the dam site is about 250 feet. The railroad however passes through the valley, and it is impossible to build the dam while the railroad holds its present line.

The arrangements which have been described will be sufficient to store the Calaveras water and transport it to the Raymundo and San Andreas reservoirs. We have yet to provide for its transit to the city. The conduit proposed from the Cañada Raymundo to South San Francisco is intended to carry 18 millions of gallons daily. The San Andreas carries nine millions of gallons and the Pillarcitos three, so that the total is 30 millions of gallons per day. It will therefore be necessary to provide for carrying about 18 or 20 millions of gallons daily from these reservoirs to the city.

We have already seen that it is possible to carry a portion of the Calaveras water to Lake Honda by laying a pipe about nine or ten miles in length from the end of the canal to the tunnel on the Pillarcitos line. A 24 inch pipe would probably be sufficient for the upper supply, carrying four or five millions of gallons daily. In order to provide for the remainder, another pipe must be laid to carry 13 or 14 millions of gallons a day. It will probably be laid from San Andreas and be made to discharge into a city reservoir at a height of 300 feet or a little less and be about 10 miles long. This pipe will have a fall of about eight feet to the mile and be 34 to 36 inches in diameter. Both of these pipes will be under light pressures, in no case exceeding 215 feet, and this only in crossing ravines.

The cost of these conduits is estimated to be $275,000, of which one-third will be due to the 24 inch pipe. The reservoir is placed at $400,000, making the total $675,000. Adding this sum to $8,016,418 we have $8,691,418 as the probable cost of making the Calaveras and Cañada Raymundo resources available in the city reservoirs.

THE LOWER CRYSTAL SPRINGS DAM.

The height of the base of this dam above city base will be about 140 feet. A dam 110 feet in height, which if made of earth would contain 300,000 cubic yards, gives a total storage of about 9,000 millions of gallons, of which two-thirds would be available for delivery through the pipe which is to be laid from the Cañada Raymundo to the city. This is about the height which a dam ought to have to store the natural drainage of the basin, but inasmuch

as this reservoir must store the water received from the Pescadero and adjoining streams or the extra supplies brought from the Calaveras, it is proposed by the Spring Valley Company to carry the dam to the height of 165 feet above the level of the valley. If we require this to be built of masonry the contents will be nearly 100,000 cubic yards, and its approximate cost $1,500,000 independent of any special expenses on account of land or vested rights.

This reservoir completes the system of the Spring Valley as now foreseen. When it is made ready for service the total capacity of the storage reservoirs will be as follows, namely:

Calaveras	25,000,000	gallons.
Crystal Springs	37,000,000	"
San Andreas and other reservoirs	8,000,000	"
Total	70,000,000	gallons.

When conduits from the Calaveras or from the coast slopes of the mountains shall be made in number and capacity to fill the Crystal Springs reservoir, then we shall reach the ultimate limit of the Spring Valley resources, as they now appear to exist. This limit is attained approximately by dividing the total storage by 900, the result being the greatest daily supply that can be expected, year in and year out. We find it to be about 80 millions of gallons. The lengths of this dam, carried to the height of 165 feet, on the top and bottom are respectively 445 feet and 35 feet. The foundations can be placed in the rock of the country.

THE SUPPLIES OF THE WESTERN SLOPE OF THE PENINSULA.

Starting from the Cañada Raymundo, twenty-five miles from San Francisco, a westerly course carries us in a few miles on and over a high, well timbered range of mountains, named on the map the Sierra Morena, which is drained to the Pacific Ocean by a number of streams, reaching the sea in distances of 10 or 15 miles. The mountains lying so close to the sea, and having elevations of two to three thousand feet, these streams necessarily have steep declivities, which enable them to carry the heavy drainage of the district. The principal streams in order going south are the Tunitas, San Gregorio and Pescadero. They drain a length of 18 or 20 miles, measured on the crest, and the width between the mountains and the sea varies, growing wider as we go south.

There are several propositions for developing these resources for water supply. They all establish the headworks at an altitude sufficient to enable the water to be delivered into the Cañada Raymundo at the height of 300 feet. The area situated at an altitude sufficient to permit its drainage to be delivered into the Cañada Raymundo at an altitude of 300 feet is about 60 square miles. One-half of this area lies on the drainage ground of the Pescadero, and nearly one-third in that of the San Gregorio.

The rapid fall of the country permits no reservoir sites of any value. The

storage reservoir must be in the Crystal Springs valley. We have already seen how prominent a feature the reservoir system is in any discussion of the production and utilization of water. The reservoir sites are the strategic points of the peninsula, and the Spring Valley Company is entrenched upon them. This consideration makes the supply of the western slope, if it is at all considerable, necessarily an adjunct and feeder of the Spring Valley system.

The region we now speak of is known by every good evidence except systematic observations to have a large average rainfall. The heavy timber and luxuriant growth of smaller vegetation—whether partly cause or partly effect of rain—are at least an evidence of it. The seasons are, of course, subject to the vicissitudes of comparative drought, but in most years there is a large fall. The district adjoins the Pillarcitos which also lies on the western slope, and of which we have records of rain for twelve years already tabulated in this report. The annual extremes, so far as known, at Pillarcitos are a maximum of 81 inches and 21 inches as a minimum, the last being the record of the present year to April 20.

The absence of reservoir sites compels the adoption of the device which we have seen applied in the case of Lock's Creek, namely, a conduit with capacity to carry a large quantity in the rainy season. During the remainder of the year the conduit will use but a small fraction of its capacity.

The number of rainy days varies very much. By the Pillarcitos records there were 53 days of rain in 1864–65, 87 in 1867–68, 79 in 1871–72, and 67 in 1870–71. The daily averages of fall on rainy days vary as follows: in 1864–65, one inch; nearly an inch in 1867–68, nearly an inch in 1871–72, and about six-tenths of an inch in 1870–71. The largest fall for any single day was on the 19th December, 1871, when 10.79 inches fell. On the same day at San Andreas 13.63 inches fell. In the week beginning on the 18th December, 1871, and ending on the 24th, 32 inches fell at Pillarcitos and 40 inches at San Andreas. At the latter point only 10 inches drained into the reservoir in the same time, which is the more surprising because none of the drainage basin is more than three miles distant from the reservoir, and in addition, the fall of the ground towards the reservoir is rapid. The record of this week has no counterpart in any other part of the history of these reservoirs; but a fall of two or three inches on each of two or more successive days is not uncommon. When an inch a day drains off the land, the 30 miles of the Pescadero will drain 500 millions of gallons in 24 hours, and 60 square miles will drain 1,000 millions of gallons. There must be a number of days in wet seasons when this amount of water runs off. There are, of course, floods when the daily drainage very much exceeds this quantity.

There are several routes by which a conduit can be taken to the Crystal Springs reservoir. One will be found described in the report of Mr. Scowden, which is understood to be based on the survey of Milo Hoadley, C. E. This plan proposed a dam 90 feet high at the Pescadero, below Peter's Fork, which will store 600 millions of gallons. The top surface of the reservoir when full

is placed at 410 feet elevation above the city base. This reservoir is to be united with the Cañada Raymundo by an aqueduct—partly canal and mainly a tunnel—which follows the face of the mountains in a northwesterly direction for about 20 miles, and in so doing crosses the San Gregorio and other streams whose waters are to be intercepted and received into the aqueduct. There are 5¾ miles of canal and 15¼ miles of tunnel on the route, the tunneling being generally distributed in convenient lengths for working. The conduit is intended to carry 125 millions of gallons per day, and the fall is 227 feet per mile.

The gaugings of these streams in January, 1875, after a drought of six weeks, was as follows:

Pescadero	2,434,100 gallons.
San Gregorio	1,415,200 gallons.
Total	3,859,300 gallons.

(See report of Mr. Scowden.)

This capacity of 125,000,000 gallons daily is about equivalent to one-eighth of an inch drained off the land, estimated at 60 square miles. If the aggregate daily flow of the streams could be limited to this sum the aqueduct would secure all the water, but for days that the flowage exceeds this amount the excess is necessarily lost, except only the quantity that is intercepted by small reservoirs. In very inclement winters a larger proportion of the rain occurs in heavy fall than in moderate years, so that it is possible that a severe winter might give us no more water for use than one that is moderate. The gaugings made in January after six weeks drought, showing a daily flowage of 4,800,000 gallons, indicate that in the summer and fall, no rain having fallen for five or six months, we may expect a quantity considerably less than four millions of gallons daily. On May 31st, 1876, the San Gregorio carried by measurement five millions of gallons daily, and the Pescadero about eight millions of gallons.

Exact observations of the daily flow of the streams for years of different types would afford the means of ascertaining definitely what yearly amounts of water could be secured, and what dimensions ought to be given to the conduit. With this information the project would be in a shape for intelligent consideration. As the case now stands, we are really ignorant of the quantity we could hope to secure in any winter, and we can only deal with the subject by generalities, and thereby reach conclusions the soundness of which may well be doubted.

There are two other propositions for bringing the western slope drainage into the Cañada Raymundo, proposed by the Engineer of the Spring Valley Company: one by a tunnel three or four miles long—from a reservoir to be constructed on the San Gregorio at a point something more than 400 feet in height—through the mountains, emerging on the head waters of the San Francisquito Creek; thence by canal to the Cañada Raymundo, entering it by

a second tunnel. The third and last proposition is to pierce the mountains by a tunnel from Pillarcitos Creek to Cañada Raymundo, near the site of Mr. Hoadley's tunnel. Instead, however, of conveying the water to this point by a masonry conduit, a combination of flume and iron pipe is proposed.

It is quite possible by one of the routes described to obtain from this source a certain additional quantity of water, which is probably considerable; but it is hardly possible now to say how much, nor at what cost.

The potable quality of these waters is admitted to be good. The worst feature about them is the discoloration, which is caused by the escape of redwood saw-dust from the mills to the streams.

If any large quantity of water is derived from these sources, it must be carried mainly in four or five months of the year, and storage for it must be provided in the Crystal Springs reservoir. This necessity for storage will—particularly if any considerable increase over our estimate of the Calaveras supply be obtained from that and the adjoining areas of the Arroyo Honda and Arroyo Valle—demand the construction of the Lower Crystal Springs dam, for the reason that there is little storage to spare in the existing reservoir in excessive years.

We have not followed the Spring Valley prospects to this final development of its resources. In order to do this with any approach to accuracy it would be necessary for us to know what supply can be depended on, not merely for the Pescadero and the adjoining areas on the western slope, but also for the areas contiguous to the Calaveras. The necessary information must come from future observation.

A systematic survey of the country, with a definite location of a conduit, can alone furnish a satisfactory basis for an estimate of the cost of bringing the waters of the Pescadero and adjoining streams into service. The size of the conduit will of course be an essential element. As three-fourths or more of the water secured must be carried off within three, four or five months, there is an obvious necessity for a large conduit, if we set out to get a large supply. The adjustment of the questions which arise, as to route to be pursued in this difficult country; as to the most judicious capacity to be given to the conduit; as to its character, whether of masonry or of iron; and the reasonable water supply that can be obtained, is under the circumstances quite complex.

We have arrived in some of the different projects at a money value for a thousand gallons of water, but without the survey and study which have been described, it will be quite impossible to bring this source of supply to the same test. We can, however, hardly pass this subject without some attempt to fix our ideas on an approximate water yield, even though the data are insufficient for sound conclusions.

The year 1867–68 had 87 rainy days, the greatest number and the greatest fall yet recorded at Pillarcitos reservoir, reaching 81 inches. If we suppose such a year to occur again, with rain falling with regularity, giving nearly an inch a day for each rainy day, and about two-fifths of an inch a day average,

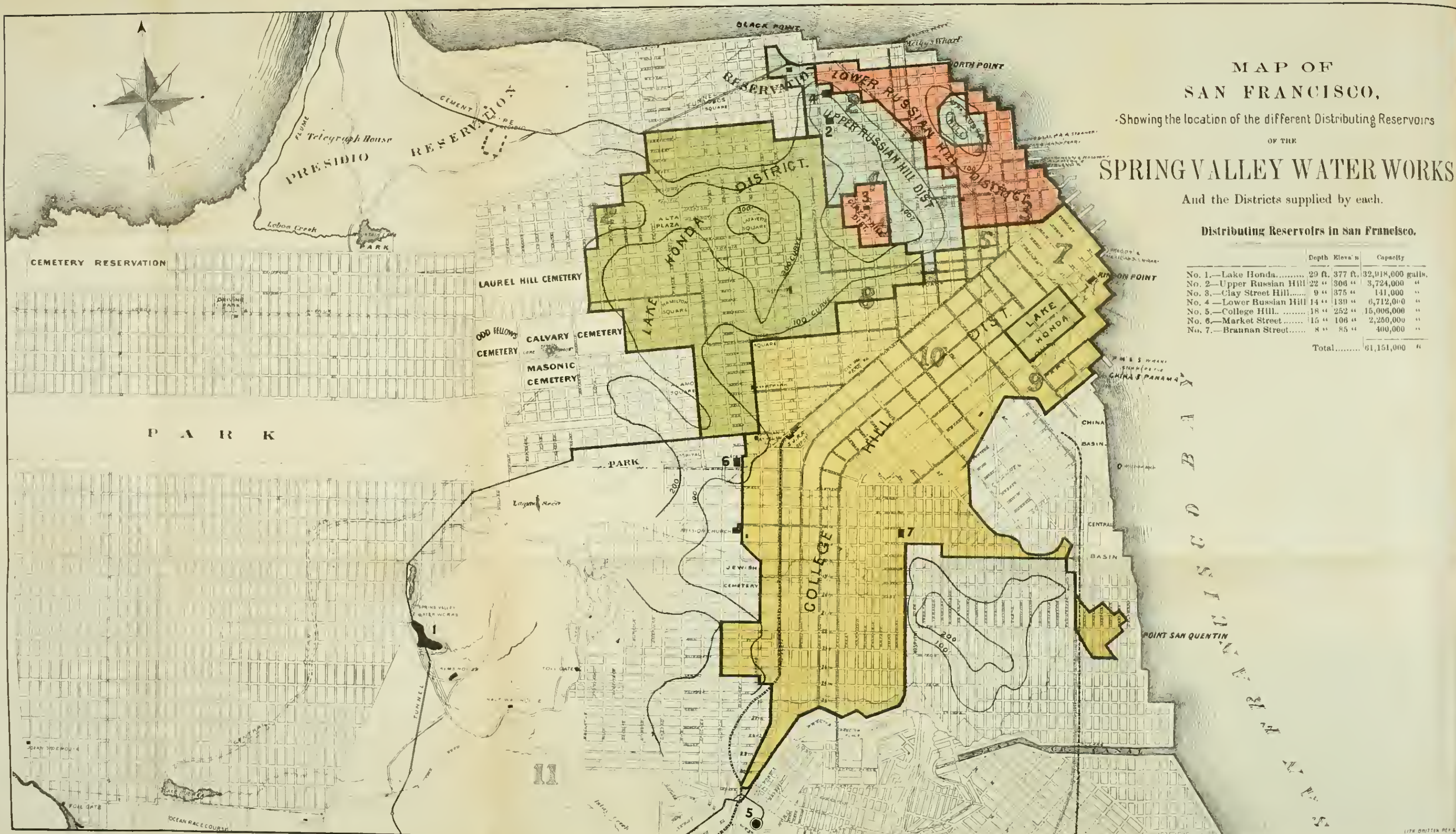
from October 15th to May 1st, which may be taken as the limits of the season, we should have a year in which the conduit might run full, say from November 15th to May 1st, a period of about 160 days. The rain that fell before November 15th would be taken up by the ground and yield a little to drainage. If we could suppose a year like this, we might get perhaps 20,000 millions of gallons in a season, provided we have the necessary storage. Neither the year we have mentioned nor any other year in California conforms to this description. The rain, instead of falling uniformly, falls as a rule in storms. December and January usually give half the fall of the year, and the fall of each of these months takes place in 15 or 20 days. For instance, in the year we speak of the fall in December was 26½ inches. This came down in 16 days, and seven-eighths of it in 10 days. During these seasons of heavy fall the streams convey more water than can be taken care of, either by the conduit or the reservoir. It is therefore lost. Perhaps in all of this winter a conduit of 125 millions of gallons capacity would have run full for 60 days. For as many more days it would have carried perhaps half its capacity, and during the year have given 12 to 15 thousand millions of gallons. This is an extreme case. The previous year (1866-67) would also have given a large supply. On the other hand, a year like the one that has just passed would not have given much more than a small fraction of this maximum supply. If we apply the test of two years like the past, yielding little or nothing and succeeding a heavy year like 1867-68, the average for the three years will probably be something like 5,000 or 6,000 millions of gallons per year, or 14 or 15 millions of gallons a day.

This conclusion is based upon a conduit to carry 125 millions of gallons a day, and upon a storage capacity of 15,000 millions of gallons at Crystal Springs. Whether the practicable yield prove to be 20 millions of gallons a day or as little as 10, it is in either case an essential part of the peninsula supply.

THE DISTRIBUTION SYSTEM OF THE SPRING VALLEY CO.

The part of the area of the city which is covered by a circulating system is divided into districts, which are supplied each from its own service reservoir, with connections which permit the higher service to supplement the lower. These districts are represented in colors on the map attached.

The area south of Market street, except six blocks on Rincon Hill—which are controlled by Lake Honda—is supplied from College Hill Service Reservoir. This district also includes about one hundred blocks north of Market street, all lying below the contour of 100 feet elevation. Within the College Hill district there are about 20 blocks having a higher altitude than 100 feet. These lie nearer the reservoir. The greater part of the district is below an elevation of 50 feet. The altitude of the College Hill reservoir is 252 feet, so that there is over the greater part of the district a pressure



MAP OF SAN FRANCISCO,

Showing the location of the different Distributing Reservoirs

OF THE

SPRING VALLEY WATER WORKS

And the Districts supplied by each.

Distributing Reservoirs in San Francisco.

	Depth	Eleva'n	Capacity
No. 1.—Lake Honda.........	29 ft.	377 ft.	32,918,000 galls.
No. 2—Upper Russian Hill	22 "	306 "	3,724,000 "
No. 3.—Clay Street Hill......	9 "	375 "	141,000 "
No. 4 —Lower Russian Hill	14 "	130 "	6,712,000 "
No. 5.—College Hill..	18 "	252 "	15,006,000 "
No. 6.—Market Street	15 "	106 "	2,250,000 "
No. 7.—Brannan Street......	8 "	85 "	400,000 "
		Total........	61,151,000 "

LITH. BRITTON REY & CO. S.F.

in the mains of 200 feet or more, except in so far as it is diminished by loss of head in transit. The area of the district is more than half of the whole area covered by the system of the Company, and its population is probably more than half that of the city.

All of the lower level of the city, which is not included in the College Hill district, is supplied from the Lower Russian Hill Reservoir, which has an altitude of 139 feet. This district is bounded on the south by California street, and on the west by Kearny street as far as Pacific, beyond which point the district is irregular in shape, and runs on both sides of Telegraph Hill as the altitudes will permit, always or nearly always considerably below the 100 foot contour.

Lake Honda and the Upper Russian Hill Reservoir, having altitudes of 377 and 306 feet respectively, control the remainder of the districted portion of the city, with the exception of 15 blocks which are supplied from the Clay Street Tank, having an elevation of 375 feet. The water cannot be delivered to this tank by gravitation, but it is pumped from the Lake Honda main. The high service system from Lake Honda and Upper Russian Hill reservoir covers all the ground above 100 feet elevation, with the exceptions before mentioned as included in the College Hill district, and also includes some land below the 100 foot contour, which more than makes up for all that the College Hill supplies above the 100 foot level. The quantity of water consumed in the upper district does not much exceed, if it equals the average of three millions of gallons a day, leaving nine or ten millions of gallons a day for the land lying below 100 foot elevation. It is quite safe to say that three-fourths of the water now used in the city is on land lying below the 100 foot contour.

The limits of these districts cannot perhaps be regarded as absolutely fixed. The College Hill district can of course be made to include land in the western addition to a height of 150 feet or perhaps 175 feet, with a proper system of mains, and still have a fair pressure.

When the conduit from the Cañada Raymundo is laid in town it will end in a reservoir having an elevation about 170 or 180 feet. This height will control the lower part of the districts now supplied from College Hill with a pressure not less than 30 or 40 pounds, and College Hill can then be applied to the middle service, extending to elevations of 150 feet or thereabouts.

If the whole of the Lobos supply—two millions of gallons—be pumped to the Upper Russian Hill reservoir, leaving the Lower Russian Hill district to be supplied from Crystal Springs, it and the Pillarcitos three millions of gallons will amount to five millions of gallons or a little more for the future supply of the district above 150 feet elevation. This will probably be sufficient for a number of years, and until some time after Calaveras is brought into requisition, when it will be possible at small expense to replenish Lake Honda from Calaveras by means that have been elsewhere described.

The mains from the College Hill and Lake Honda reservoirs are 22 inches in diameter, a small portion of the last-named being 30 inches. The whole

pipe system consists of the following lengths and sizes, including the wrought iron mains from the reservoirs just mentioned:

2,572 feet........	30 inch	Wrought Iron	11,293 feet........	10 inch	Cast Iron
15,341 "	22 "	" "	154,083 "	8 "	" "
17,896 "	22 "	Cast "	263,784 "	6 "	" "
1,202 "	20 "	" "	240,842 "	4 "	" "
23,694 "	16 "	" "	88,159 "	3 "	" "
61,511 "	12 "	" "	881,371	......Total.	

The total length of the street system is 881,371 feet, and its weight is as nearly as can be estimated 38,000,000 pounds.

The condition of the pipes in the ground cannot be known. The earlier ones were probably laid without being covered with a bituminous coating. In such cases tubercles are apt to form in the pipe and obstruct the flow. This effect is more noticeable as the water is soft, and in some qualities of iron more than in others. The water derived from San Andreas and Pillarcitos is not however very soft.

The demands upon a circulation system are very unequally distributed. As a rule, the demand is at a maximum from six to ten o'clock in the morning, falling in a well regulated system to little or nothing in the night. If there is any considerable loss of water after nine o'clock at night, it may be credited to waste. This may be termed the diurnal variation.

There is also a weekly variation in that Monday requires a larger supply than any other day in the week, while Sunday consumes less than any other day. A series of warm days introduces another cause of increased demand.

Last of all, fires create a large local demand for a certain time, greater or less according to circumstances. A distribution system ought to be proportioned to meet the largest of these demands.

The practice of engineers varies in regard to the proper capacity of mains as related to the daily demand. The least that is allowed is a capacity of twice the daily demand, which means that the pipes shall be able to carry in 12 hours the consumption of 24 hours. The practice varies from this to six times the demand, which requires the pipes to carry in four hours the consumption of the whole 24 hours.

The College Hill district is supplied by a 22-inch main, which passes through Valencia and Market streets. This main has recently been extended as far as Sansome Street. There is also a 16-inch main on Valencia Street, and one of 12-inch on Mission Street. In the report of the Superintendent of the Spring Valley Company, dated June, 1875, the suggestion is made that the 16-inch pipe on Valencia Street can be taken up for use elsewhere. It can however hardly be spared. The present capacity of these mains, sup-

plemented by the $2\frac{1}{4}$ millions of gallons in the Market Street reservoir, is none too great for the district which they supply.

The Spring Valley company is engaged in remedying the deficiencies, which have existed and still exist in the populous districts by laying larger mains. They have recently extended the 22-inch main down Market Street to Sansome, and they propose to lay a 16-inch main from Market along Seventh Street to Townsend Street; along Townsend to the eastward and back to Market. This main will be of great value to the populous district south of Market Street. Another improvement consists in uniting the dead ends which have existed in many places.

The Company has no map of its circulation system in a compact form, which would permit a study of this subject in detail. The system, however, is admitted to need the introduction of large mains, either to replace the smaller pipes originally laid, or to supplement their want of capacity by bringing to their aid a reservoir close at hand, from which they can be replenished. This may be done by a network of mains, surrounding districts made up of several blocks.

It is proper to remark that the pressures in the pipes in the lower part of the city are very considerable, and in excess of those found in most other cities, being in the neighborhood of 100 lbs. at night, and often 60 or 70 lbs. in the daytime. This fact justifies the use of smaller pipes than can be permitted when the pressure is less.

It is plain that a new system, based upon our clearer conceptions of the future wants of the city, could have an unity and proportion which cannot be expected of one that has grown up under the circumstances of the past growth of the city.

For the purpose of making comparisons of cost of the various projects, a study has been made of the existing system of pipe service, with the view of ascertaining what it would cost to reproduce it, or to provide another system equally as good. The result of this study indicates \$2,000,000 to be a liberal value of the existing pipe system. In its present condition, it may for purposes of comparison be held barely adequate for the distribution of the amount of water which the Company claim to supply to the city, namely 13 millions of gallons daily.

A comparison and study of the distribution systems of some important cities reveal very essential differences in the sizes of the mains. For instance, Chicago has in her street service three gallons capacity for each foot of pipe, Boston has $6\frac{1}{8}$, San Francisco has $2\frac{63}{100}$, and St. Louis has six. Measured by population, Chicago has in her pipes 14 gallons per head, Boston has more than 25, San Francisco has $7\frac{7}{10}$, and St. Louis has about 12. In length Chicago has 410 miles, Boston 320 miles, San Francisco 163, and St. Louis 178. The proportion in mileage of four and three inch pipes is larger in San Francisco than in any of these cities, amounting to 38 per cent. of the total pipeage, whereas the percentages in Chicago, Boston and St. Louis are respectively 33, 10 and 9. In St. Louis no pipes smaller than six inch have

been laid for several years. An absence of the large mains from 24 inches upwards is also noticeable in our system as compared with these cities. Boston has nearly seven per cent. of her pipeage in mains of 24 to 48 inches. San Francisco has four per cent. of 22 and 30 inch, of the latter only one-third of one per cent. In St. Louis one-eighth of the mileage is 20 inch and above to 36 inch. In San Francisco the proportion is a trifle over one-twentieth.

LAGUNA DE LA MERCED.

There yet remains to be noticed an extremely reliable source of supply, which lies closer to the city than any which has been mentioned. This is the Laguna de la Merced, which is within the corporate limits of San Francisco, although beyond the exterior limits of its settled district.

It has an area of about 331 acres. It is fed by springs which deliver to the lake, with remarkable uniformity, a quantity which has varied but little from five millions of gallons per day, as measured by such approximate means as were possible, in a number of visits beginning in May, 1876, and extending to February, 1877. The true daily supply can only be ascertained with certainty by observations of the outflow, continued through a series of seasons, embracing the maximum and minimum rainfall. This has not been done.

Some gaugings were begun in September, 1874, under Mr. Scowden's directions, and continued for a short time. The maximum measurement of the rainy season was not included in the gaugings. The maximum result obtained in this series was 5,680,434 gallons per day. The minimum gauging is not stated in the report.

We do not know the full effect of a season of drought upon this supply. There is a good reason to suppose from the character of the drainage ground and the mode in which the water is carried to the lake, that the supply will not be reduced in dry seasons to anything like the extent that the other drainage basins are affected. The really reliable supply in a series of years of varied rainfall cannot therefore be stated with the definiteness that is desirable. It has been for the past year about five millions of gallons daily, and at times perhaps six.

The overflow of the lake reaches the ocean through a channel a mile or so in length. The lake has high banks, which on the west are of sand and on the other shores of sand and loam, overlying a stratum of hard pan, impermeable to water. The rainfall penetrating this layer of soil, reaches a stratum inclining towards the lake, and trickling with little velocity, takes a year or more to deliver to the lake what it received from the clouds in a few months. The soil plays the part for the lake that the snow does in the Sierra. It holds back and moderates the drainage of the land during the rainy season, to pay it out with some regularity during the year.

It is sometimes suggested that the uniformity of flow implies a distant source, and that the supply is artesian in its character, but the phenomena

observed seem to be entirely in harmony with the local circumstances, and to be explained by them.

The drainage basin of the lake is about eight square miles in area. It extends to and includes a part of the western slope of the San Bruno Mountains. This circumstance may give a higher rainfall over the district than that which has been observed in San Francisco. No observations of rainfall have, however, been kept. The drainage basin is a plain without any trees or foliage, and a great part of it is under cultivation.

The level of the lake has maintained itself, when visited during the past year, at nearly the same height, and latterly an inch or two higher than in the earlier visits. The supply from the springs just about equalled the overflow.

The proper way to utilize this water for city consumption would be to place a dam across the outlet, which is but a few feet in width, and at the same time place two pumps, or one perhaps might answer, with a sufficient reservoir. With two pumps a small reservoir of a capacity of 20 or 30 millions of gallons, at a proper height, will be all that is required. If a single pump is used, it would be proper to provide a larger reservoir to keep up the supply during any temporary stoppage of the machinery. From this reservoir a large main would supply the city. This proposition supposes the supply to be utilized, independently of the Spring Valley or any other system.

The height of the surface of the lake appears, by the notes of surveys that have been made, to be about two feet above the city base. The height of the reservoir selected by Mr. Scowden is 340 feet. The distance from the pumphouse to the reservoir is 5,865 feet. Other sites having about the same advantage exist in the neighborhood on the plain.

The cost and character of the constructions necessary to store the water in the lake, to establish the pumps and force main and to build the reservoir, can be stated with tolerable accuracy. When however we pass beyond this and begin to plan a distribution system for the city, the question arises at once, shall the pipes be laid all over the city or shall the system be confined to a particular district? and if so, what district shall be selected as the one to receive its supply from Lake Merced?

The supply being estimated at five millions of gallons daily, which amount is insufficient for the whole city with its present population, it is plain that if the city should desire water from this source it must be supplemented by another supply. The arrangements which ought to be made for utilizing the water will, for this reason, depend on circumstances outside of this particular supply. For instance, if Lake Merced is treated as a part of the peninsula system, the natural plan would be to pump either into the Pillarcitos or San Andreas conduits, both of which pass within practicable pumping distance of some point of the lake.

The Pillarcitos conduit discharges into the Lake Honda distributing reservoir and supplies the highest district of the city. The San Andreas conduit terminates at College Hill reservoir and delivers the main supply of the city. To reach the Pillarcitos flume, the water would have to be pumped about 410

feet in height through a conduit 6,000 feet long, while the lift to the San Andreas conduit would be something less than 300 feet with a conduit about 8,000 feet in length.

The cost of pumping is an essential element in the economy of the system. We have the cost in the various cities of the country which are supplied by this means. A very great difference is noticeable in different cities. The varying price of coal, the different heights, the amount pumped in a given time, the proportion of time of action of the engines as compared with the time they are at rest, are among the circumstances which affect the cost in so varied a degree. The cost of fuel is larger here than in any of the other cities in the country. This fact and the general price of labor will prevent us from securing so cheap service as can be afforded in some Eastern cities.

The cost of pumping one million gallons one hundred feet high is stated in official reports to be as follows for the cities named:

1875 Brooklyn	$8 79	1875 Roxborough	$10 31
1875 Jersey City	11 27	1875 Cincinnati at three different Stations	9 61 7 95 11 60
1875 Philadelphia, at Schuylkill Station	17 05	1875 Louisville	8 45
1875 Philadelphia, at Delaware Station	12 98	1875 Chicago (for 9 months)	9 00
1875 Belmont	7 85	1875 St. Louis, for 6 mos. Low service High "	11 94 5 18

The study which has been made of this subject renders it probable that, with a well arranged system, the pumping at Lake Merced could be done for 11 cents per million gallons one foot high. In this amount is included an allowance of 4 per cent. on the cost of machinery for repairs. Assuming this rate, the cost of raising five millions of gallons 340 feet high becomes, with allowance for friction head, $191.50, which represents the daily expense. The coal is assumed to cost $7 per ton at the pumping station, and the hourly consumption is seven pounds per horse power. For the purpose of maintaining the supply during a period when the engine may be disabled, we have the choice of building a reservoir of considerable capacity or of placing a second pump in position. The latter alternative is the more economical. Without intending to express an opinion as to the relative economy or advantage of different types of pump, the Worthington Duplex, which is extensively used in the East, is assumed for the purposes of estimate. If there be differences of cost and advantage between this and other machinery, these differences will not make any very essential alteration in the estimate.

A reservoir at 340 feet elevation, built in a substantial manner in two divisions holding 20 millions of gallons, may be expected to cost not more than $240,000. Two pumps of capacity to deliver five millions of gallons daily each can be placed in position for $90,000. The other expenses attending the

establishment of the works—including the purchase of land for reservoir, right of way, force main 24 inches diameter, engine house, gates and tenements—ought to be provided for $160,000, making a total of $500,000, to which we may add 10 per cent. for contingencies, giving a gross sum for all expenditures of construction of $550,000, which contemplates arrangements of the best character. The yearly interest on this at six per cent. is $33,000, or per day $90.41. It will be remarked that an engine of five millions of gallons capacity is kept in reserve.

The daily expense of pumping was found to be	$191 50
Add interest	90 41
Total daily expense	$281 91

This sum delivers five millions of gallons daily into the reservoir at 340 feet elevation. The cost per thousand gallons is therefore 5.6 cents.

If, instead of pumping to the reservoir, the water is delivered into the Pillarcitos flume, the capital cost will be reduced by the expense due to the reservoir. The force main becomes somewhat longer, and the pumps a little heavier and more expensive. The height is assumed to be 410 feet. The daily cost of pumping becomes at same prices about $231.00. The interest account will be reduced so that the gross sum of daily expenses—pumping and interest—will amount to about the same as in the former case, and the cost of delivering water into the Pillarcitos line by a permanent pumping system will not probably vary much from 5.6 cents per thousand gallons. Pumping to the San Andreas line, the cost will be about 4.5 cents per thousand gallons.

In this calculation no account has been taken of the cost of the property to the city, nor for any expenses of management, nor for any system of distribution. These last two items are so intimately connected with and dependent upon the arrangements by which the water may be delivered in the city—whether through the Spring Valley or by an independent system—that it seems useless to attempt at present to estimate upon them. The first item, namely, the cost of the property, may be the subject of negotiation, and its amount cannot now be known.

Under these circumstances it seems hardly necessary to pursue the calculation further at present.

The general arrangements for utilizing the water are proposed to be essentially the same as those recommended by Mr. Scowden. The reservoir capacity is, however, very much reduced.

There are possible and even probable circumstances, under which this supply may become indispensable to the city. If the coming winter proves as unfruitful in water production as the one just past has been, this lake will be a very important and perhaps the only resource which can stand between the city and a great disaster. If the supply maintains the same dimensions which it has preserved during the past year, it may be sufficient, with economical consumption, to carry the city during the year.

The analysis of the water will be found in the table of water analyses (see Appendix A), which is attached to this paper. A considerable growth of tule exists in the shallow water around the edges of the lake. The water has a vegetable taste, which is generally found to be the case where the tule abounds, and which for this reason is attributed to the tule growth. It is possible that the tule may be exterminated by proper measures.

The distance from the well populated part of the city to the lake is about five miles. and to the edge of its drainage basin the distance does not exceed three miles. With the growth that the city is expected to have, twenty or thirty years may place a considerable population within the drainage basin of Laguna Merced, where now there are but a few scattered houses. When the drainage basin or any considerable portion of it becomes a real part of the city, and is laid out in streets lined with houses, the lake will be poisoned by the sewage, unless special means are taken to prevent this result.

The thorough way of protecting the lake from the effect of sewage would be to keep the drainage basin free or nearly free from population. This course can hardly be regarded as practicable. The possession by the city of the land surrounding the lake, with a system of works adapted to carry to the sea the drainage of the portion of the city which is naturally tributary to the lake would, of course, be effective in protecting it, but if the view which this Report takes of the mode, by which the Lake is fed, be correct, this protection would involve the loss of a large portion of the water which it now possesses.

If, on the other hand, the supply can be regarded as artesian in its character, the protection would involve no sacrifice of its daily supply.

Although it is thought, for the reasons that have been given, that the Laguna Merced cannot be regarded as a proper and pure supply for all time in the future, yet for a number of years to come it will be free from objection on account of noxious drainage, and in the meantime it may be the means of saving the city from a great calamity.

NOTE.—The area of Lake Merced is stated in Mr. Scowden's map to be 331 acres. The area, as taken by a planimeter from the Coast Survey sheets, is 382 acres.

FEATHER RIVER.

A proposition to bring a water supply from the FEATHER RIVER will be found in the appendix. This proposition was presented at so late a period of the investigation, that it could not receive a detailed examination.

The first feature of this proposition is the proposal to construct a tunnel at or near the Golden Gate, the city taking no rlsk of failure, but paying a specific price after its completion. This feature is essential. Without the tunnel the proposition falls. Some views have already been expressed on the subject of this tunnel. It cannot be deemed impracticable. The tunnel being constructed, it is proposed to take the water out of Feather River by a canal, and carry it to a point on the foothills 977 feet in elevation. At this

point the water enters a reversed syphon, (the length of which is not stated,) which crosses the Sacramento Valley and discharges on the foothills of the Coast Range at an altitude of 697 feet. From this point to San Francisco the conduit is an open canal located on the flanks of the mountains, syphons being used only for the passage of the valleys which are encountered on the route. The line of this canal has never been located and its length is not known.

The want of specific data of quantities, length and circumstances prevents a critical examination of the project, but there are certain general considerations that have a bearing upon the subject, which are worth remark.

In this project the conduit is mainly canal, iron syphons being used only when indispensable. We have no means of knowing the length of the conduit. All told it must be 250 miles, of which hardly a sixth is closed.

In the other projects which have been considered, the length of canal has been only one-third or one-fourth of the whole conduit. It is thought that for a conduit which is mainly canal, the specifications which governed in the first case can hardly be applied to the second with propriety. The principal modification which would be necessary would be a substantial lining of masonry, concrete or brick, to take the place of dry stone lining. This modification would be required to prevent the loss of water by absorption on so long a line. While adding something to the expense, it would, however, have the advantage of a large carrying capacity.

It is thought that the water supply may be carried in canals under proper regulations. Among these are such arrangements as will prevent cattle or other animals having access to it. Canals on side hills, as these must necessarily be, are peculiarly subject to accidents from slides of earth or snow, where the altitude is sufficiently high. For these reasons a closed conduit is to be preferred.

The advantage lies also with the closed conduit, so far as evaporation is concerned. This is an element that can hardly be neglected. Take 100 miles of canal which has a top width of 20 feet. Placing the loss by evaporation at five feet for the season, the loss will be 400 millions of gallons for the season, or more than a million of gallons for each day in the year. It is usual to assume evaporation at about five feet for the season. It is at times, with an exceptional hot wind from the land, known to be as much as $\frac{5}{8}$ of an inch per day. It would hardly be safe to take less than five feet for the season.

The cost of a water supply is, in a measure, proportioned to its length. This has, perhaps, the longest route of any of the projects submitted for your consideration.

Some of the alternative propositions looking to a supply from the Coast Range would deserve consideration, if the great tunnel were built. At present no sufficient reason occurs to the undersigned for going to Feather River.

QUANTITY OF WATER REQUIRED.

The increase in the population of the city in the past seven years—as stated in the City Directory—and the daily quantities of water consumed—as stated in the reports of the Spring Valley Company—are shown in the following table:

YEAR.	POPULATION.	INCREASE PER YEAR.	DAILY CONSUMPTION.	
			Total.	Per Capita.
1870	150,000	....	6,038,000 galls.	40 galls.
1871	165,000	15,000	6,600,000 "	40 "
1872	173,000	8,000	7,453,000 "	43 "
1873	184,000	11,000	8,600,000 "	47 "
1874	196,000	12,000	9,650,000 "	49 "
1875	225,000	29,000	10,930,000 "	48 "
1876	267,000	32,000	12,320,000 "	46 "
1877	295,000	28,000	13,850,000* "	47 "

*Estimated.

A large part of the population is supplied from other sources than the Spring Valley. At present the Spring Valley Company estimate that they supply 220,000 people. The average consumption on this basis is about 60 gallons per head of actual consumers.

The consumption in American cities varies very much, and shows a decided tendency to increase in all, or nearly all cases. In 1874, the daily consumption per head was as follows for the cities named:

New York	90 Gallons	Boston	70 Gallons
Chicago	80 "	Philadelphia	56 "
St. Louis	45 "	Baltimore	50 "
Brooklyn	60 "	Cincinnati	53 "
Milwaukee	25 "	Providence	30 "

In Providence water is delivered by meters.

In 1860, Chicago consumed 43 gallons per head; and Cincinnati, 31. In 1867, New York consumed 62 gallons; Philadelphia, 46; and Boston, 55. The reports of other cities show a similar increase per head.

The consumption in American cities is very much greater than in most European cities. Dublin and Glasgow show a consumption of 60 and 52 gallons respectively; Paris, 38; London, 33, Liverpool, 30. These are imperial gallons, five of which are nearly equivalent to six United States gallons.

When the supply is sufficient for extravagance, there is no special motive in restricting the consumption in any manner, but in cases where the water is

pumped, or where the natural and reasonable consumption trenches closely upon the supply, the question at once assumes a pecuniary phase and the same motives exist for checking extravagance as apply to all business operations in the world at large.

Chicago, Brooklyn, Philadelphia, St. Louis and Cincinnati pump their water, and the expense of the works bears a direct relation to the consumption. This has not been strictly true of New York until recently. A few years ago the supply was so large that no restriction was desirable, but increased waste, more than increased population, has brought the city to the necessity of facing a large expenditure for a further supply.

It is generally admitted that the increased consumption in American cities is the direct consequence of waste. This waste seems to be partially due to defective pipes in streets and buildings, but more particularly to positive and premeditated waste by leaving faucets and valves open, notably in water closets.

The opinion is expressed in the Chicago report of 1875 that it is a very moderate estimate to say that one-half of the water is wasted. In Cincinnati, between the hours of 12 and 4 Sunday morning, when it is to be supposed that the needful consumption is almost nothing, it was found that water was drawn off at the rate of six millions of gallons per day, five millions of which is believed to be wasted. This is about one-third of the daily consumption. A similar condition of affairs exists in St. Louis.

The consumption in New York has at times been at the rate of 100 gallons daily, and in Boston as much as 90 gallons. By a careful system of inspection and a partial introduction of metres, the maximum consumption in Boston has been considerably reduced.

It is generally admitted that the only practicable way of reducing the consumption to proper limits, and of distributing the burden fairly among consumers is by a comprehensive system of metres. Any practicable system of inspection can but partially remedy the abuse of waste, and in addition, its operation involves a certain amount of invasion of the privacy of homes, so that it is liable to become obnoxious and therefore inefficient. The objection to the general use of metres is the great expense they involve.

It seems to be the general opinion of those, who have investigated the consumption in Eastern cities, that a daily allowance of 50 gallons per head is abundant. The discussions in San Francisco have generally assumed a supply of 100 gallons per head.

The financial bearing of the suitable consumption has great importance for all municipalities, but the circumstances of the San Francisco supply give peculiar force and value to the subject. The position of San Francisco—at the point of a peninsula, separated by an arm of the sea from the main body of

the land—and the climatic conditions of the country, combine to make water more valuable than it is in any of our cities. The great length and weight of conduit which the Sierra sources require, or if we confine ourselves to the nearer sources of the Peninsula or Calaveras, the large reservoirs which are essential to store the excess of one year to make up for the deficiencies of other years—in either case, involve a scale of expense not required for any other city.

For these reasons, water can never be supplied in San Francisco at as cheap a rate as it can be in any of the Eastern cities. There are therefore special reasons for an economical use of water. On the other hand, the absence of rain for months at a time requires a larger allowance for streets, sewers, parks and gardens than is needed in our Eastern cities. If the unnecessary waste can be kept down to small limits, 50 gallons a day per head will leave a large margin for purposes not purely personal. The actual necessary consumption for one person with an average mode of life does not probably exceed 20 gallons a day, and it is often estimated much below this rate.

Again, it is possible to use the sea water for some purposes—for instance, cleaning sewers and street sprinkling.

The extent of manufacturing industries using steam boilers is an important element in the consumption of water. In this respect San Francisco is perhaps not equal to the other large cities of the country.

Under these circumstances, it is thought that 60 gallons per head ought to be the maximum to be contemplated at present, with a possible minimum of 50 gallons. Estimating our present population at 300,000, and assuming for the future a growth equal to that of New York at the same stage, we may expect to have 500,000 people in 1887 and 800,000 in 1897. The daily consumption on the basis of 60 gallons will be in 1887 30 millions of gallons, and 48 millions in 1897. With an allowance of 50 gallons per head, the consumption per day will be in these years respectively 25 and 40 millions of gallons.

FINAL COMPARISON.

Having concluded the description of the various projects, we are permitted to gather in compact form, for purposes of final comparison, the characteristic facts and conclusions which have been illustrated in this Report. In the light of these facts, it is possible to consider the various prejects in their relations to the cardinal points of water supply, which are quantity, quality, safety and cost, and to balance the respective advantages and disadvantages in the scale of intelligent criticism.

THE SPRING VALLEY.

The characteristic feature of the Spring Valley supply, present and prospective, is the unusual size of its reservoirs, which is made indispensable by two facts—first, that no considerable stream is embraced within its drainage basins; and secondly, by the climatic fact that we have periodically two successive seasons which give no drainage, or only so much as provides for the evaporation from the surface of the reservoirs. On the hypothesis that the reservoir capacity is adjusted to the water production, we may state an approximate rule for determining the greatest daily supply that can be relied on, which is to divide the capacity of the reseivoirs by 900.

Under this test of drought, and with reservoirs holding 42,000 millions of gallons, the greatest supply that can be allowed to the Spring Valley has been stated to be 47 millions of gallons daily, of which 30 millions may be derived from the Calaveras, with its drainage area of 100 square miles; and 17 millions from Canada Raymundo, San Andreas and Pillarcitos, having an area of 27 square miles. To this amount may be added a daily supply of two millions of gallons from Lobos Creek, which will, however, in a few years be polluted by the drainage of the city to such an extent as to forbid its use for domestic purposes. The probable value of the minimum supply is 45 or 46 millions of gallons.

The water production of the Pescadero and adjoining streams on the western slope of the coast mountains, and of the Arroyos Valle and Honda, adjoining the Calaveras, are not included in this estimate of quantity. The Arroyos Hondo and Valle are worth little for water supply, unless suitable reservoir sites exist within their limits. No such sites are known as yet. There is no information as to rainfall in these districts. There is a strong presumption that it is less than in the Calaveras.

The Coast District is well watered, but it has no reservoir sites on the western slope. The only suitable storage reservoir is that at Crystal Springs. When the lower dam is built, it will be possible to obtain from the Western Coast a supply of water, but its amount and the cost of obtaining it cannot be definitely ascertained from any existing information.

The construction of the Lower Crystal Springs dam will add about eight miles of area to the producing drainage basin, and four or five millions of gallons to the daily production. The cost of this improvement includes the purchase of a large tract of land and the extinguishment of vested rights. These elements of cost cannot be estimated with accuracy. Adding this amount of five millions, the maximum limit of daily production from the CALAVERAS and SAN MATEO drainage grounds, year in and year out, becomes 52 millions of gallons.

The heights of the dams, which impound these large quantities of water, vary from 183 feet at Calaveras to 83 feet at Cañada Raymundo. The Calaveras dam may be reduced to the height of 165 feet, provided the Isabel Valley reservoir is built. If the storage in the Calaveras is reduced below 25,000 millions of gallons, the production will be diminished in a corresponding ratio. Whatever element of uncertainty or danger there is in the Spring Valley supply is to be found in the height of its dams.

The Spring Valley supply possesses important advantages in its proximity to the city, the light pressures which are on most of its conduits, and in its possession of a revenue with no competition.

The San Mateo reservoirs hold 16,000 or 17,000 millions of gallons, and they all are within 20 miles of the city. The short lines and light pressures remove all danger of serious inconvenience from breaches in the conduit. If a breach occurs, the proximity of the shops makes it easy to repair. The Calaveras is not much more than 40 miles from the city. Its conduit has, however, a heavy pressure of 575 feet for a distance of seven miles. The amount of this pressure, and the distance over which it is exerted, are very much less than the corresponding elements in the gravitation lines crossing the San Joaquin Valley.

If the city succeeds to the rights of the Spring Valley, it comes at once into the possession of an income which is available to meet the interest on the purchase money. If the city brings water from another source, it is not only without income for three or four years spent in construction, but it enters a field where the Spring Valley will be in competition. The financial bearing of these circumstances is evident.

The law of recurrence of dry years in pairs, as shown in the records of the past 27 years, makes it probable that next winter will bring little rain and add little or no water to the Spring Valley reservoirs. If this should be the case, the Company or the city, if it succeeds the Company, will be obliged to draw a large part of next year's supply from Lake Merced. This will require the establishment of pumps to lift the water to the Pillarcitos conduit or San Andreas conduit, through a height of 400 feet in one case, and about 300 feet in the other.

The low supply of water now held by the Spring Valley Company is due to

mistaken policy, in postponing the construction of the dam at the Cañada Raymundo. If this reservoir had been in condition for service in 1875, it would now contain five thousand millions of gallons instead of a few hundred millions.

The Company is now establishing pumps at Crystal Springs to lift the water from the Cañada Raymundo to the Pillarcitos conduit, a height of about 400 feet. This is necessary to supplement the high service supply in the city, and is rendered necessary by the failure to store any water in the Pillarcitos reservoir last winter. The true duty of the Cañada Raymundo reservoir is to supply the part of the town lying below 100 feet in elevation. In order to do this, a conduit 20 miles long must be laid to connect with the city, and a distributing reservoir, holding 30 millions of gallons or thereabouts, must be built at a height of 170 or 180 feet near the city. The cost of making the Cañada Raymundo reservoir available for its natural office is estimated to be one million dollars.

The Pillarcitos reservoir, which furnishes the greater part of the high level supply, holds less than 1,100 millions of gallons. The small size of this reservoir deprives it of the advantage of the law of average. A bad winter will always curtail the upper supply, no matter how much water may be stored in lower reservoirs. It will then be necessary to pump from the lower reservoirs for the service of the higher level, at every recurrence of a winter of drought, until the Calaveras water is introduced. It has been shown how this supply may be delivered in Lake Honda. For all average years the supply from Pillarcitos, aided by the pump at Black Point, will be sufficient for the high level until the Calaveras water is introduced.

A large portion of the conduits of the Spring Valley is in wood, temporary in character and requiring frequent repairs. The Lock's Creek conduit, nearly 20 miles long, is mainly of wood. The Pillarcitos flume is two miles long. Portions of the conduit from Pillarcitos to the city are of wood, as also a part of the line from Lobos Creek. It will be remembered that the objects of the Lock's Creek and Pillarcitos side flumes are to pick up certain quantities of water which otherwise would escape the reservoirs, and that they add about one-third to the effective drainage basin of the San Andreas and Pillarcitos reservoirs. Without them the production of these reservoirs, instead of being nine millions of gallons, would be about six millions of gallons.

The street system of pipes owned by the Spring Valley is defective in the absence of large mains. The present value of the pipes does not exceed, if it equals, $2,000,000.

The quality of the water supplied by the Spring Valley Company is good. The drainage ground of the San Andreas and Pillarcitos covers little arable land. The supply from Cañada Raymundo will be derived under similar circumstances, and promises to be equally good. Although the water is im-

pounded during the winter, and may be stored two years before it is used, the depth of the reservoirs and the prevalence of strong winds throughout the summer, giving motion to the surface, act powerfully to aerate the water, and are sufficient to preserve its sweetness.

The Calaveras Valley is also a good drainage ground, subject to as few influences of contamination as that of almost any other city supply known to us. Its precipitous character will always prevent it from being thickly populated. It will, however, always be a pasture ground to the extent that its wild grasses can afford subsistence to cattle and sheep.

The hardness of waters derived from different grounds varies to some extent, and while none of it can be called soft water, it has always been used for steam purposes in the city without complaint.

The cost of making the Calaveras and Cañada Raymundo supplies available has been found to be $8,691,418, including in this sum interest on the cost during construction.

The works included in this estimate are the following:

1—The Calaveras dam.

2—The outlet tunnel and conduit across the Santa Clara Valley.

3—A canal 22 miles long, from the end of the conduit to the San Andreas reservoir.

4—A conduit from the northern end of this canal to Lake Honda.

5—A conduit from San Andreas to a reservoir near the Industrial School.

6—A conduit from the Cañada Raymundo to South San Francisco.

7—Two distributing reservoirs, one at the extremity of each of the last named conduits.

The capital cost of the completed works will be found by adding the purchase price to the sum just mentioned, namely, $8,691,418.

The construction of the Lower Crystal Springs dam to the height of 165 feet above the valley will give a storage capacity of 37,000 millions of gallons. The Calaveras reservoir will contain 25,000 millions of gallons; the other reservoirs, 8,000 millions of gallons. The total storage capacity will be 70,000 millions of gallons. If this capacity cannot be materially increased—and our knowledge of the country indicates that no essential increase is to be expected—the ultimate resources of the Spring Valley system, tried by the test of two successive dry seasons, cannot under our rule be expected to exceed 80 millions of gallons per day. This limit will, however, only be attained when provision is made to bring to Crystal Springs from other sources—the Pes-

cadero and elsewhere—sufficient water to fill the Lower Crystal Springs reservoir.

We are now prepared to construct a table, designated as B, which shall show approximately the cost of a thousand gallons of water derived through the Spring Valley system, for different degrees of consumption up to the full development of the Calaveras works. The table is constructed on the basis of expenditure described in the discussion of the Spring Valley system. The order and amounts of disbursements in the future may or may not correspond with those assumed for our purposes, but any variation from this order will not make any essential difference in the amounts.

Table B is one of a series, which aim to place the cost of the various projects in a shape for comparison, which shall be clearly intelligible to every one. Inasmuch as it is impossible to foresee every future expense or contingency, such comparison as we are now able to make can hardly claim to be minutely accurate. The expenses of supervision on the various lines will not be exactly the same, but it is thought better to leave them to balance each other, the differences not being very great. The expenses of city administration ought to be the same in all cases. They may therefore be omitted in the comparison. The extension of the street pipe system in future years will be the same. We are however required to assume a value for the Spring Valley system, which has been elsewhere stated.

The elements which remain to be taken into account in this table, in order to arrive at the cost of a thousand gallons of water, are interest on capital cost including interest during construction, and permanent expenses of pumping. The pumping expense refers to the establishment at Black Point, and does not include the Crystal Springs pumping. The latter is regarded in the light of a necessity called for by the failure to catch water in the Pillarcitos reservoir last winter. It is a temporary arrangement. The true method of delivering water from Crystal Springs is by a conduit to South San Francisco.

The capital cost assumed in the table is $12,000,000, including in this sum the cost of a conduit from Cañada Raymundo to the city and a reservoir. The sum of $12,000,000 has no significance except as an assumption upon which to base a calculation. Its presence does not, therefore, express any opinion pro or con in reference to the value of the Spring Valley Works. Similar tables, designated by the first letters of the alphabet, will afford the means of comparing the different costs.

TABLE B.

SPRING VALLEY WATER WORKS.

Showing the Cost of a thousand gallons of Water, estimated on the basis of Interest on Capital Cost, and expenses of Pumping, all other expenses being omitted.

Purchase Price...$11,000,000
The Conduit from Cañada Raymundo.. 1,000,000

Total Cost...$12,000,000
Pumping Expenses at Black Point, estimated at $30,000 yearly.

Million Gallons Delivered Daily.	Yearly Expense.		Total Daily Expense.	Cost in Cents per Thousand Gallons.
	Interest. (6 per cent.)	Pumping.		
10	$720,000	$30,000	$2,055	20.6
11	720,000	30,000	2,055	18.7
12	720,000	30,000	2,055	17.1
13	720,000	30,000	2,055	15 8
14	720,000	30,000	2,055	14.7
15	720,000	30,000	2,055	13.7
16	720,000	30,000	2,055	12.8
17	720,000	30,000	2,055	12.1
18	720,000	30,000	2,055	11.4
19	720,000	30,000	2,055	10.8
	Here enters Interest	on Cost of Tunnel,	Conduit and Dam,	
	123 feet high, Cal	averas—Cost........	...........$3,400,000	
	Contingencies......	....	 340,000	
	Interest for one year	, half time of Con	struction.. 224,000	
	Total............	....	.... $3,964,400	
	Yearly Interest on	same, to be added to	Yearly Interest Ex-	
	pense	....	....$237,864	
20	$957,864	$30,000	$2,707	13.5
21	957,864	30,000	2,707	12.9
22	957,864	30,000	2,707	12.3
	Here enters Interest	on Cost of raising	Dam—Cost..$400,000	
	Contingencies......	....	 40,000	
	Interest for six mon	ths, half time of Con	struction.... 13,200	
	Total.............	....	.............$453,200	
	Yearly Interest on	same, to be added to	Yearly Interest Ex-	
	pense	....	..............$27,192	
23	$985,056	$30,000	$2,781	12.1
24	985,056	30,000	2,781	11.6
25	985,056	30,000	2,781	11.1
26	985,056	30,000	2,781	10.7
	Here enters Interest	on Cost of raising	Dam as above $27,192	
27	$1,012,248	$30,000	$2,856	10.6
28	1,012,248	30,000	2,856	10.2
29	1,012,248	30,000	2,856	9.8
30	1,012,248	30,000	2,856	9.5

TABLE B.

SPRING VALLEY WATER WORKS—Concluded.

Million Gallons Delivered Daily.	Yearly Expense.		Total Daily Expense.	Cost in Cents per Thousand Gallons.
	Interest. (6 per cent.)	Pumping.		
	Here enters Interest	on Cost of raising	Dam as above $27,192	
	Also Interest on Cost	of Conduit from San	Andreas to	
	Lake Honda—Cost,	$100,000.		
	Interest	....	 6,000	
	Total to be added to	Yearly Expense, Inte	rest Account $33,192	
31	$1,045,440	$30,000	$2,946	9.5
32	1,045,440	30,000	2,946	9.2
33	1,045,440	30,000	2,946	8.9
34	1,045,440	30,000	2,946	8.7
35	1,045,440	30,000	2,946	8.4
	Here enters Interest	on Cost of raising	Dam as above......	
	....	.. ..	.. .. $27,192	
	Also Interest on	Cost of Conduit and	Reservoir—	
	Cost, $575,000.			
	Interest...........	....	 34,500	
	Total to be added to	Yearly Interest Ex	pense....... $61,692	
36	$1,107,132	$30,000	$3,115	8.7
37	1,107,132	30 000	3,115	8.4
38	1,107,132	30,000	3,115	8.2
	Here enters Interest	on Cost of raising	Dam as above......	
	....	....	....$27,192	
39	$1,134,324	$30,000	$3,190	8.2
40	1,134,324	30,000	3,190	8.0
41	1,134,324	30,000	3,190	7 8
42	1,134,324	30,000	3,190	7.6
	Here enters Interest	on Cost of Complet	ing Dam—	
	Cost..............	....	............$500,000	
	Contingencies......	....	 50,000	
	Interest for six mon	ths, half time of Con	struction. . 16,500	
	Total.............	....	............$566,500	
	Interest on same to	be added to Yearly	Interest Expense....	
	....	....	.... $33,999	
43	$1,168,314	$30,000	$3,283	7.7
44	1,168,314	30,000	3.283	7.5
45	1,168,314	30,000	3,283	7.3
46	1,168,314	30,000	3,283	7.1
47	1,168,314	30,000	3,283	7.0
48	1,168,314	30,000	3,283	6.8
49	1,168,314	30,000	3,233	6.7
50	1,168.314	30,000	3,283	6.6

It would be an error to assume the tabulated prices as the rates at which the city could afford to sell water, in case she succeeds to the Spring Valley system. This will appear from the following considerations.

The charges due to expenses of management, to the sinking fund and to the extensions of the pipe system, have not been considered in this table. The administration of the Spring Valley Company costs now something more than $100,000 per year, and it must increase in some ratio with the growth of the city. The pipe extension may be expected to cost quite $100,000 per year. The sinking fund may be what a sound regard for the credit of the city will require. None of these sources of expense enter into this table.

But this is not all. These charges and all others must be borne by a part of the water supply. A certain fraction cannot in the nature of the case be taxed. In this fraction are included the unmeasured waste and the water furnished for public purposes—for street sprinkling, fires, public buildings and grounds. The relation of this fraction to the whole supply, particularly as regards waste, will depend much upon the strictness of administration. With a loose system of inspection the fraction may be quite one-half. It may be taken for granted that the selling price can never be less than twice the tabulated rates. It will probably be found between three and four times these rates when the sinking fund begins to be collected from the consumers.

LAGUNA MERCED.

Laguna de la Merced is at present an important element in the Peninsula supply. It is estimated to be able to furnish about five millions of gallons daily. This supply is derived from springs, which are fed by the rainfall on about eight square miles of area. The rain is absorbed by a porous soil, and is there stored and paid out at a rate approaching uniformity throughout the year. This circumstance gives reliability to the supply. It prevents a partial failure of rain from being immediately felt, and makes the supply more nearly constant than is the case in the other Peninsula supplies.

The proper way of using this supply is thought to be in conjunction with the Spring Valley system. This can be done either by pumping to the San Andreas conduit through a height of 300 feet, or to the Pillarcitos conduit through a height of 410 feet. In the former case the force main will be about 8,000 feet in length and in the latter about 6,000. The cost of a thousand gallons, including pumping expenses and interest on the outlay expended in construction, will be 4.5 cents in the first case and 5.6 cents in the second, the purchase money of the property not being considered.

This supply of water will be indispensable, in order to preserve the city from disaster, should the coming winter prove to be the counterpart of the one just past.

THE LINES FROM THE SIERRA NEVADA.

The distinguishing features of the Sierra Lines are their length and the great pressures, which must be met in the construction of the inverted syphons.

Going by the head of the Bay the Mokelumne Line is 175¾ miles in length, 38 miles being canal and 137¾ iron pipe.

The line from the South Fork of the American is 202¼ miles in length, 45 miles being canal and 157¼ iron pipe.

The iron conduit on each line is composed of two syphons, one of which extends from the end of the canal to Livermore Pass, and the other from Livermore Pass to San Francisco.

For the Blue Lakes or Mokelumne Line, the syphon which crosses the San Joaquin is 331,748 feet in length, and in this distance there are about 22 miles in which the pressure is not less than 900 feet. The remaining syphon, extending from Livermore Pass to San Francisco, is 395,523 feet, of which 130,000 are under a pressure of 500 feet and more. The highest pressure is 555 feet. This applies to a delivery of 300 feet high in San Francisco.

On the line from the South Fork of the American, the San Joaquin syphon has a length of 434,855 feet, of which 45 miles have a pressure equal to or exceeding 900 feet. The western syphon is the same as that for the Mokelumne line.

These maximum pressures are in some cases just below 400 lbs. to the square inch, and in some cases above it. It has been previously stated in this report that it is possible to deal with these pressures, using a well made conduit of sufficient strength, and the opinion has been ventured that breaches, in a properly proportioned and a properly laid conduit, may be expected to be infrequent.

It is proper to point out in what degree they will be serious, when they do occur. It will be remembered that no gates are provided in these syphons. The reasons which govern in this matter have been stated. In the absence of gates a break in the lowest part of the line will nearly empty the pipe. The mass of water will pour out of the break at a high velocity, and tear up the ground in a violent manner. It is not probable that the breach will occur in more than one place at a time, for the reason that the pressure in the pipe will be instantly relieved by the increase of velocity of discharge due to the rupture. The restoration of the pipe will not, however, be merely the insertion of one or more new pieces, but will also involve the reëstablishment of the foundation of the pipe, which may be a more serious labor than the mere replacement.

The question may be asked, what will cause a breach. It may occur by the foundation of the pipe being washed out by floods, or by a settlement of the ground, which may occur from several causes, among which the following may be mentioned: A slight leak at one or more joints of the pipe may take place, which will soften the ground about and under the pipe; and if this

point is on the side of a hill, this softening will be particularly apt to result in a yielding of the ground. The support being removed from a portion of the pipe, an extra strain is brought upon a joint which must now sustain the pressure due to the withdrawal of support from the adjoining pipe. This may in time cause the joint to yield, and the results which have been described to follow.

The breaches in the canal are likely, however, to be much more frequent than ruptures in the pipe. It will be recalled that for a few miles the canals issuing from the rivers are obliged to follow along the steep flanks of the mountains. They are, therefore, subject to injury from any movement of the ground above them, which results in slides. The slope of the canal on its upper side is in many places necessarily steeper than the natural angle of repose of the earth. When this bank becomes softened by the rain, or snow accumulates above on the mountain, slides may be expected. These falling into the canal obstruct its flow, and the water rises until it reaches the height of the bank and then runs over, and in a few minutes destroys the banks for some little distance. There is no way of preventing this result, and it may be expected to occur in each winter in a more or less serious degree.

These dangers necessitate the reservoirs which have been provided along the line. Experience alone can prove exactly what degree of reservoir capacity will be necessary. We have now provided 500 millions of gallons at the head of the Blue Lakes pipe line, 230 millions at Livermore Pass between the two syphons, and about 250 millions in San Francisco.

The reservoir at the head of the pipe being full, the canal may be broken for 25 days without interrupting the supply to the pipe, the draft being 20 millions of gallons daily. The Livermore Pass reservoir will keep up the supply under similar circumstances for 10 or 11 days, and allow this time for repairs in the San Joaquin Valley syphon. The San Francisco reservoir has 10 or 12 days' supply to tide over any possible interruption of the supply from Livermore Pass. The reservoir capacity along the line ought to be made as large as future investigation may prove to be possible.

The special advantages of the Sierra Nevada supply have been fully described in the previous part of this Report. They consist in the certainty of the supply and the quality of the water. Whatever may be said in criticism of the quality of water derived from any other source proposed for your consideration, no charge of impurity can be brought against water derived from the Sierra. The country is uninhabited for the most part, and must always so remain. There are no influences, present or prospective, which can affect the quality of the water unfavorably.

The mountainous district is the region of maximum snow and rainfall. The rivers draining this region run full for the greater part of the year, and for that time afford an abundant supply of water. There is, however, a portion of each year in which rivers, draining 300 square miles of mountainous country, carry less than even the minimum daily supply that can be contem-

plated for this city. This fact requires a certain amount of storage in the mountains, which shall supply the demand during the low tages of thes rivers.

The lakes and meadows in the upper altitudes afford, as a rule, admirable facilities for storage. These reservoirs, in connection with the natural flow of the rivers, assure the quantity beyond any reasonable doubt.

Quantity and quality are two well established points for any contemplated supply from the mountains. On the other hand, it will appear from the tables of cost of a thousand gallons that the Sierra supply is more expensive than other and nearer sources. It may also be regarded as well established that the expense of maintaining a line is in some sort of ratio to its length. A canal 50 miles long, situated as the mountain canals are on the flanks of steep mountains, will require a careful supervision. A man for each five or six miles of canal line, and one for every 10 or 15 miles of pipe line, will be required to patrol the lines, repair slight damages, and to report those of a more serious character.

The canals, which form the upper link of the supply line, are intended to deliver 100 millions of gallons per day to the reservoir at the head of the pipe lines. The conduit from the head of the pipe line to the city has been estimated to carry either 22 or 35 millions of gallons a day, these being regarded as the maximum capacity of a 40 inch and a 48 inch pipe respectively, with a fall of 7.43 feet per mile. It has been regarded as possible that the deliveries of these pipes may be as low as 20 and 32 millions of gallons.

It may be a question whether it is better to to lay down the larger or the smaller conduit. The larger conduit will cost 40 per cent. more than the smaller, but it will deliver 60 per cent. more water. The capital cost per million gallons will therefore be less by the larger conduit than with the smaller. On the other hand the city will have to carry the interest on about $4,000,000, which represents the difference of cost between the larger and the smaller conduits for a term of years, before the consumption passes the 20 or 22 millions of gallons.

To illustrate this point, let us suppose the Spring Valley to bring into use the Cañada Raymundo supply. The daily supply from all her sources in action will be 19 millions of gallons. If the city brings in the smaller conduit, the total and combined supply will be 40 millions of gallons. With a consumption of 60 gallons per capita, this amount will supply 667,000 persons, or with a consumption of 50 gallons 800,000 people may be supplied. We allow twenty years for the growth of the city to the latter limit. The interest account may therefore, under the latter hypothesis, run for 20 years before the larger capacity is really needed. The interest at six per cent. more than equals the original capital difference in the proportion of 120 to 100. If the foregoing be accepted as a probable state of circumstances, the conclusion will follow that it is economical for the city to build the smaller conduit at present, in preference to the larger.

Some engineering considerations point in the same direction. The scale of conduit, in length, size and pressure, is unprecedented. It will be a more

prudent and conservative course to build the smaller than to undertake the larger at once. The delivery of these pipes in the present state of hydraulic knowledge, cannot be regarded as well established. It is possible that these pipes may deliver more water than we have at present a right to assert. On the other hand the price of iron is low beyond all precedent. When the time comes to duplicate the iron conduit, the cost of the material may be thirty or possibly fifty per cent. in excess of present rates. The consideration, that the city must in a few years duplicate the line from the Sierra, ought to be borne in mind.

No limit has been assigned for the life of iron conduits, whether on the Peninsula or elsewhere. Our knowledge on this point is limited by the experience in California. We know that pipes are in good condition now which have been in use 12 and 15 years. The ruling consideration, as far as life is concerned, will be found in the thoroughness of the bituminous coating, which is relied upon to protect from corrosion.

The storage, which is essential in the Sierra projects, will be found in the high altitudes, and generally in positions inaccessible in winter, except by snow-shoe travel. The season when the stored water will be needed is in the latter part of the summer and fall, at which times the reservoirs may readily be reached.

The facilities for storage vary very much in different drainage areas. Lake Tahoe is unexcelled. Next to Lake Tahoe come the lakes on the head of the South Fork of the American, which have been elsewhere described. The facilities on the Mokelumne basin have been described. They cannot be regarded as so favorable as the El Dorado. On the other hand, the conduit of the latter is much more expensive than that of the Blue Lakes.

Although the cost of storage on the Mokelumne will exceed that required on the South Fork of the American, the Mokelumne project taken as a whole is considerably cheaper than the El Dorado. This results from the expensive character of the conduit belonging to the latter project, which more than makes up for the advantage in storage.

Referring to the table of mountain reservoirs on page 19, it will be seen that the minimum water product is stated to be for the Upper Blue Lake 945,000,000 gallons, Lower Blue Lake 630,000,000, Twin Lake 472,500,000, and Lake Valley 1,417,500,000. The amount of storage that ought to be provided for the smaller conduit has been stated at 2,000 millions of gallons. The temporary dam of cribs and stone now built at the Upper Blue Lake, will impound the minimum quantity 945,000,000 gallons. We may secure the required remainder in the Lake Valley reservoir which, by the estimate to follow, will cost $280,500; or we may secure the necessary storage in the Lower Blue and Twin Lakes at a somewhat greater cost.

In a few years it will become necessary to replace the temporary dam at the Upper Lake. The cost of a permanent dam in hydraulic masonry, which is the proper construction for these distant sites, will probably be $27.50 per cubic yard, including in this 10 per cent. for contingencies. The stone can be obtained at little cost. The labor and cement will be very expensive.

The cost of the dams at all the reservoir sites will be by this estimate as shown in the following table:

	Maximum Height of Dam.	Cost.
Upper Blue Lake	42	$224,977
Lower Blue Lake	49	235,290
Twin Lake	26	134,750
Lake Valley	70	280,500
Upper Bear River	70	346,500
Lower Bear River	70	682,000
Cold Creek	70	687,500

When the time comes for a second conduit to be laid to the city, it will be necessary to build another reservoir. The Upper Bear River site will be suitable for a conduit of 20 or 25 millions of gallons daily.

Appendix B contains the last proposal from the promoters of this project. It appears that the omission of the reservoir near the town of Livermore, which is not now thought necessary, and the gain of 14 miles of canal, induce them to make a reduction of $500,000 in their price, $300,000 being due to the canal and $200,000 to the reservoir. The price as now stated is $13,500,000. The Lake Valley reservoir is not included, neither is the right of way for the canal and pipe. The cost of these items is assumed at $380,000. Adding this sum to the proposed price, it becomes $13,880,000. This sum includes all expenses to the city. It remains to add $3,000,000 for terminal reservoir and street pipe system. This is the same amount which has been charged to the other projects. The total now becomes $16,880,000. Add to this nine per cent., which is the interest for eighteen months at six per cent. a year, namely, $1,519,200—this being interest accrued during three years of construction—we have the sum of $18,399,200 which represents the cost to the city of the completed works. This sum will bear interest at six per cent., making a yearly charge of $1,103,952.

On this basis we are enabled to calculate Table C, showing the cost of a thousand gallons for consumption, running to the full capacity of the pipe, which is 22 millions of gallons daily. When this consumption is reached, it will become necessary to lay a new conduit and build a new reservoir in the mountains. We assume the new conduit of the same capacity to cost $10,000,000, and the reservoir at Upper Bear River to cost $350,000. The interest on this sum—$621,000—enters at a consumption of 22 millions a day and is carried to 44 millions a day. When this consumption is reached a third conduit will be required. The table, however, stops at 44 millions per day. The expenses of administration, street pipe extension, repairs and sinking fund are left out of consideration, these having been omitted in the other comparative tables.

TABLE C.

BLUE LAKES LINE.

Cost of Works..	$13,500,000
Right of Way, and Lake Valley Reservoir...............................	380,000
Reservoir and Street Pipe Service.......................................	3,000,000
Interest during half time of Construction, at 6 per cent.....	1,519,200
Cost to City when complete..	$18,399,200

COST $18,399,200.

Millions of Gallons per Day.	Yearly Interest Expense.	Daily Interest Expense.	Cost in Cents per 1,000 Gallons.
10	$1,103,952	$3,024 52	30.24
11	1,103,952	3,024 52	27.49
12	1,103,952	3,024 52	25.21
13	1,103,952	3,024 52	23.27
14	1,103,952	3,024 52	21.60
15	1,103,952	3,024 52	20.16
16	1,103,952	3,024 52	18.90
17	1,103,952	3,024 52	17.72
18	1,103,952	3,024 52	16.80
19	1,103,952	3,024 52	15.92
20	1,103,952	3,024 52	15.12
21	1,103,952	3,024 52	14.40
22	1,103,952	3,024 52	13.75
Here enters Cost of on same, $621,000,	a new 22-million gallon to be added to the Yearly	Conduit—Cost, $10,350, Interest Expense.	000. Yearly Interest
23	$1,724,952	$4,725 89	20.55
24	1,724,952	4,725 89	19.73
25	1,724,952	4,725 89	18.90
26	1,724,952	4,725 89	18.18
27	1,724,952	4,725 89	17.50
28	1,724,952	4,725 89	16.88
29	1,724,952	4,725 89	16.30
30	1,724,952	4,725 89	15.75
31	1,724,952	4,725 89	15.26
32	1,724,952	4,725 89	14.77
33	1,724,952	4,725 89	14.32
34	1,724,952	4,725 89	13.90
35	1,724,952	4,725 89	13.50
36	1,724,952	4,725 89	13.12
37	1,724,952	4,725 89	12.77
38	1,724,952	4,725 89	12.44
39	1,724,952	4,725 89	12.12
40	1,724,952	4,725 89	11.81
41	1,724,952	4,725 89	11.53
42	1,724,952	4,725 89	11.25
43	1,724,952	4,725 89	10.99
44	1,724,952	4,725 89	10.74

THE SAN JOAQUIN RIVER PROJECTS.

The SAN JOAQUIN supply has not been distinctly classified as belonging to the Sierra Nevada. These mountains, however, contain the sources of the river.

The influences of mining operations, irrigation and population on the quality of the water have been discussed. The quantity flowing in the river in its lowest stage is probably much more than the city will ever require, which dispenses with the construction of storage reservoirs in the mountains. The river is nearer to the city than any other source draining the Sierra. The route by way of Livermore Pass is 84 miles in length, and that by way of Antioch, Martinez and Oakland is 134 miles in length.

Both projects require pumping, one over Livermore Pass a height of 740 feet; the other pumps twice, once at the headworks to a height sufficient to deliver the water to a receiving reservoir in San Francisco a few feet above tide, and again the water is raised at San Francisco to heights sufficient to supply the different levels of population districts. The quantity of pumping required to cross Livermore Pass exceeds very considerably what is required in the other project.

The relative expenses are shown in tables prepared for the purpose, which show the Livermore Pass route to be the cheaper at first up to a delivery of 16 or 17 millions of gallons per day. The shore route is the cheaper afterwards. The difference is not great until the limit of the Livermore Pass project—namely, 25 millions of gallons a day—is reached. At this point the interest account of the Livermore Pass route is increased by the construction of a new conduit, so that the shore route becomes decidedly cheaper from this point onwards.

The internal pressure on the shore line conduit is produced by the low service pumps. It varies with different velocities of the water. When the pumps are stopped, the water ceases to flow and the pressure runs down to little or nothing. The conduit being level or nearly so, the hydrostatic pressure is nothing or next to nothing. Gates and exit valves may therefore be provided at convenient distances with safety to the pipe, so that examination and repairs are facilitated and the control of the water secured.

The opportunity for expansion by degrees, which permits the expense of duplicating the conduit to be spread over a term of years, is an important financial advantage which belongs to the shore route.

The limit of capacity of the conduit will be 47 millions of gallons a day, if it is a double-riveted pipe, or 55 millions per day if welded. The upper conduit 12 miles in length is proportioned to carry 100 millions of gallons a day, so that with a duplicate conduit from Marsh's Landing to San Francisco this quantity would be the proper capacity of the works, even with a welded joint.

The element of cost depends upon the expense of pumping, and the principal circumstance which affects the expense of pumping is the value of coal.

An hourly consumption of seven pounds of Mt. Diablo screenings for each effective horse-power developed is the basis of the calculation of the quantity and cost of coal.

The labor account results from a plan of engines and boilers arranged especially in the beginning for doing the work in the most economical way. This account is lower than exists in any of the Eastern cities, and possibly it may have to be increased.

Table A (page 94) contains the cost per thousand gallons delivered from the San Joaquin by the Livermore Pass route. Table D, which contains similar items relating to the shore line, is prepared from the following data, all sources of expenses being omitted except interest on capital cost and pumping expense. The interest account will be made up in this way:

Cost, as per offer of San Joaquin and San Francisco Water Works Company, for works complete	$13,000,000
Deduct estimated cost of machinery on which interest is charged under the head of pumping expenses	400,000
Balance	$12,600,000
Add cost of reservoir, and street system equal to the one now existing	3,000,000
Total	$15,600,000
Add interest at 6 per cent. for 1½ years, half the time used in constructing works	1,404,000
Actual cost of works to city when completed	$17,004,000

which is the sum to bear interest at the rate of 6 per cent. per annum. The yearly interest will be $1,020,240.

The cost of pumping per thousand gallons is transferred from Tables V and VI, on pages 85 and 86.

TABLE D.

SAN JOAQUIN AND SAN FRANCISCO WATER WORKS.

Showing Cost per 1,000 gallons, on account of Interest and Pumping Expense, all other Expense being omitted.

Million Gallons per day.	Yearly Interest on $17,004,000 at six per cent.	Daily Interest.	Cost in Cents per 1,000 Gallons.		
			Interest Account.	Pumping Account.	Total.
10	$1,020,240	$2,795 18	27.95	3.20	31.15
11	"	"	25.41	3.08	28.49
12	"	"	23.29	2.98	26.27
13	"	"	21.50	3.00	24.50
14	"	"	19.96	2.93	22.89
15	"	"	18.63	2.93	21.56
16	"	"	17.47	2.89	20.36
17	"	"	16.44	2.81	19.25
18	"	"	15.53	2.80	18.33
19	"	"	14.71	2.76	17.47
20	"	"	13.98	2.72	16.70
21	"	"	13.31	2.91	16.22
22	"	"	12.66	2.90	15.56
23	"	"	12.15	2.88	15.03
24	"	"	11.65	2.88	14.53
25	"	"	11.18	2.93	14.11
26	"	"	10.75	2.94	13.69
27	"	"	10.35	2.93	13.28
28	"	"	9.98	2.93	12.91
29	"	"	9.64	2.94	12.58
30	"	"	9.32	2.94	12.26
31	"	"	9.02	3.03	12.05
32	"	"	8.73	3.04	11.77
33	"	"	8.47	3.03	11.50
34	"	"	8.22	3.07	11.29
35	"	"	7.99	3.13	11.12
36	"	"	7.76	3.15	10.91
37	"	"	7.55	3.14	10.69
38	"	"	7.36	3.16	10.52
39	"	"	7.17	3.19	10.36
40	"	"	6.99	3.20	10.19
41	"	"	6.82	3.26	10.08
42	"	"	6.65	3.32	10.02
43	"	"	6.50	3.36	9.86
44	"	"	6.35	3.40	9.75
45	"	"	6.21	3.45	9.66
46	"	"	6.07	3.49	9.56
47	"	"	5.95	3.52	9.47
48	"	"	5.82	3.56	9.38
49	"	"	5.70	3.62	9.32
50	"	"	5.59	3.62	9.21
51	"	"	5.48	3.72	9.20
52	"	"	5.38	3.78	9.16
53	"	"	5.27	3.85	9.12
54	"	"	5.18	3.88	9.06
55	"	"	5.08	3.94	9.02
56	"	"	5.00	4.00	9.00

At this point a portion of the conduit will have to be duplicated. The development of the project is, however, continued no further. If it were it would show a further decline in cost.

Table E is derived from Tables A, B, C and D. Its contents are in a favorable shape for comparison.

TABLE E.

CONSOLIDATED TABLE SHOWING THE COST IN CENTS OF ONE THOUSAND GALLONS OF WATER ON ACCOUNT OF INTEREST AND PUMPING EXPENSES.

Consumption in Millions of Gallons per day......	From Table B.	From Table C	From Table A.	From Table D.
	Spring Valley..	Blue Lakes.....	San Joaquin by Livermore Pass. (S. F. & S. J. W. W.)	San Joaquin by Shore Line. (S. J. & S. F. W. W.)
	Cents.	Cents.	Cents.	Cents.
10	20.6	30.24	28.44	31.15
11	18.7	27.49	26.40	28.49
12	17.1	25.21	24.70	26.27
13	15.8	23.27	23.27	24.50
14	14.7	21.60	22.04	22.89
15	13.7	20.16	21.04	21.56
16	12.8	18.90	20.16	20.36
17	12.1	17.72	19.33	19.25
18	11.4	16.80	18.59	18.33
19	10.8	15.92	17.93	17.47
20	13.5	15.12	17.33	16.70
21	12.9	14.40	16.80	16.22
22	12.3	13.75	16.31	15.56
23	12.1	20.55	15.86	15.03
24	11.6	19.73	15.45	14.53
25	11.1	18.90	15.07	14.11
26	10.7	18.18	....	13.69
27	10.6	17.50	....	13.28
28	10.2	16.88	....	12.91
29	9.8	16.30	....	12.58
30	9.5	15.75	....	12.26
31	9.5	15.26	....	12.05
32	9.2	14.77	....	11.77
33	8.9	14.32	....	11.50
34	8.7	13.90	....	11.29
35	8.4	13.50	....	11.12
36	8.7	13.12	....	10.91
37	8.4	12.77	....	10.69
38	8.2	12.44	....	10.52
39	8.2	12.12	....	10.36
40	8.0	11.81	....	10.19
41	7.8	11.53	....	10.08
42	7.6	11.25	....	10.02
43	7.7	10.99	....	9.86
44	7.5	10.74	....	9.75
45	7.3	....	....	9.66
46	7.1	....	....	9.56
47	7.0	....	....	9.47
48	6.8	....	....	9.38
49	6.7	....	....	9.32
50	6.6	....	....	9.21
51	....	....	....	9.20
52	....	....	....	9.16
53	....	....	....	9.12
54	....	....	....	9.06
55	....	....	....	....
56	....	....	....	....

Table E is an objective point, which this Report has constantly kept in sight. The conclusions which it embodies are of a very important character, for they are, under the conditions which we have been compelled to assume, final in regard to cost, which is regarded as one of the cardinal points of investigation.

The project which comes second in cost is the shore line conduit from the San Joaquin River. If it were not for the detour of 60 miles which this line is obliged to make in order to head the Bay, the difference of cost would be much less. It is this and other physical features of the country which give the Spring Valley Company the advantage.

When, however, we undertake to estimate the degree of this advantage, the results of Table E require to be qualified by the objections to the Spring Valley system, which have been stated in the description of it and repeated in the final comparison. It would, therefore, be an error to estimate the value of the Spring Valley system at a capital cost, the interest of which would make the cost of a thousand gallons the same as can be delivered by another route. Such an estimate of its value would be too high.

The other cardinal points are quantity, quality and safety.

With respect to quantity, the San Joaquin and the Sierra projects fulfill all requirements of the future, the latter in part by storage in reservoirs, but mainly by the natural flow of the rivers. The San Joaquin affords all needed quantity by its natural flowage, and without the intervention of reservoirs.

The quantity that can be supplied by the Spring Valley system has already been stated. It is regarded as certain that a population of 750,000 can be supplied with 60 gallons a day per head from existing resources increased by the Calaveras. The maximum limit of production, when all adjoining sources are included, cannot much exceed if it equals 80 millions of gallons per day.

With regard to quality, it is less easy for an engineer to speak with confidence. Quality depends upon constituent elements, the technical investigation of which belongs to the chemist's laboratory. Such investigations as have been made do not permit us to condemn any of the sources of supply on the score of quality. They are all believed to be good. If, however, one is to be preferred to another, common judgment would give the distinction to the supply direct from the Sierra.

As regards safety, it has been explained that canals on the steep flanks of mountains are certain to be breached at times. Ruptures of conduit may be expected to be more frequent as the line is longer and serious in proportion to the pressure. Dams may break, and the consequences will be disastrous in proportion to the height. Breaches of dams and conduits are or ought to be within the control of sound construction. While there are differences of safety in the various projects, they are not such as to exercise a controlling influence on the choice of the city to the exclusion of other considerations. It is only when other considerations are nearly balanced that these differences ought to control.

It may be asked whether there are any other water sources other than those heretofore mentioned, which may at any time in the future become available for the city supply.

A reference to the map of the State will show that a drainage district, which includes Mt. Diablo on the north and Mt. Hamilton on the south, and which is for the most part made up of mountains of greater or less elevation, finds an outlet to the plains at Niles Station. Alameda Creek carries the surplus water drainage from this district, which includes within its borders the Upper Calaveras and the Arroyos Honda and Valle, already considered under the head of Spring Valley. The area of this district is quite 500 square miles. Near Suñol Station there is a very good site for a dam, and above, in Calaveras Valley particularly, the ground lies very favorably for a very large reservoir. Alameda Creek runs down in the summer to a very small creek, carrying five millions of gallons a day, or perhaps less. In the winter it is often a torrent. In such winters as the past has been it remains a small stream throughout the season. The daily value of this supply will depend upon the capacity that can be given to the reservoir, which is known to be very large. The line of the Central Pacific Railroad runs over the dam site and makes the project at present impracticable. The question of water supply may, however, in the future take on so much importance as to make the location of the railroad a secondary matter. A dam 100 feet in height would maintain the water, when the reservoir is full, at an altitude of about 330 feet.

A distance of 45 miles by way of Ravenswood, or of 57 miles around the head of the Bay, would bring the water to the city limits. It could be delivered by gravitation at a height of 150 or 160 feet, which is sufficient for the supply of the lower and most populous district in the city. The direct route would involve the crossing of the Bay at a point where the width is 1¼ miles.

PUTA CREEK.

Another source is Puta Creek, which has already been mentioned, but in connection with the proposition to build a tunnel at or near the Golden Gate, it deserves more notice than it has received.

The Board of Commissioners have not authorized any surveys of the drainage basin or of the conduit lines. The examination of 1874 included this project as a part of Clear Lake, and surveys were made of two lines of conduit, neither of which, except in part, applies to the line of conduit passing the Golden Gate.

Puta Creek is a tributary of the Sacramento River. It, like all the small streams of California, runs down to little or nothing in the latter part of the summer. The upper part of its drainage ground is both mountainous and well timbered. Mt. St. Helena and Cobb Mountain both lie on the borders of the drainage district. These two characteristics, namely, mountains and timber, indicate a good degree of rainfall. There are no accurate observations of rainfall known to exist.

Under these circumstances, it follows that the floods of winter must be stored. A reservoir site of large dimensions exists at and below the hamlet of Guenoc. Its area and capacity are stated by Mr. Scowden to be respectively 10½ square miles and 52,000 millions of gallons. Two dams will be required, one having a height of 105 feet, and the other of 84 feet. If these

dams were made higher, the area of land overflowed when the reservoir is full would not be much increased. Ten feet additional height would add about 22,000 millions of gallons to the storage capacity. Our information does not permit us to say exactly what part of the total storage capacity would be above the outlet tunnel and therefore available. The drainage area due to this reservoir is about 124 square miles.

It is hardly possible at present, in the absence of knowledge of the flowage of the creek in any year or series of years, to determine with accuracy the supply of water which may be derived from this source. We have, however, in our previous studies, learned the value and relation of storage capacity in investigations of this kind. When the storage capacity is given we are well advanced towards a conclusion. The capacity of the reservoir assumed at 52,000 millions of gallons will store rather more than two feet of water drained off the land. At Clear Lake, ten miles distant, the recorded rainfall has been as much as 66 inches. With such a rainfall, the reservoir would probably be filled. On the other hand, the rainfall at Clear Lake has been as low as 16 inches in a year.

The evaporation on 10½ square miles of water surface will be as much as 11,000 millions of gallons a year. If we suppose two dry years to succeed each other, each affording only water enough to supply the evaporation during the year, that is 11,000 millions of gallons, which is equivalent to six inches drained off the land, it follows that the product of one year must supply the consumption of three. The large proportionate area of reservoir in reference to area of drainage basin exposing so much surface to evaporation, will hardly justify us in adopting the rule which was used in discussing the Spring Valley supplies. This rule would give too large a product. The rule was generally stated to be as follows: Divide the storage capacity by 900, the quotient being the daily supply. If we deduct the first year's evaporation, namely, 11,000 millions of gallons, from the available storage capacity and divide the difference by 900, we shall have as good a conjecture as can be made at present, and one that will probably be safe. Such a course of calculation would give us 40 or perhaps 45 millions of gallons, as the conjectural daily product of the drainage basin of Puta Creek above the reservoir site.

One of the dam sites lies across the valley of the Creek where it runs between high bluffs. The base of the dam is 130 feet long as measured on the ground, and its top, for a maximum height of 104 feet, has a length of 477 feet. The foundation has not been exposed, but inasmuch as there are rocky bluffs on each side, it can hardly be anything but the rock of the country. A hard trap rock is found conveniently which, it is thought, would answer for a building material. If these opinions are correct, it will follow that the dam ought to be of masonry. The contents of an earthen dam at this point are 367,613 cubic yards.

The second dam site lies across Willow Slough, near Crabtrees', with hills on either side. Appearances indicate it to be doubtful whether rock *in situ* can be reached at a convenient depth. If it cannot be reached, the dam must be

made of earth. Otherwise it would be preferred to make this also of masonry. The dimensions of an earthen dam at this site, as laid down by Mr. Scowden's survey are, length on top and bottom, 807 and 875 feet; width on top, 50 feet; cubical contents of embankment, 290,000 cubic yards.

The surface of the reservoir, when full, will be at a height of 1,015 feet above city base. The floor of the outlet tunnel as now proposed is at reference 983. It may possibly prove desirable to lower this tunnel 10 or feet.

The general route by which it is proposed to reach the Golden Gate is by way of Butte Creek; thence to Pope Creek. Both creeks are tributaries of Puta Creek, entering it below the reservoir. From Pope Valley the line passes into Child's Cañon, which is a tributary of Napa Creek. It then crosses Napa Valley about ten miles above the town of Napa, passes over the mountain ridge into Sonomo Valley two miles to the north of the town of Sonoma, and again over another ridge to a point 1½ miles west of Petaluma. It passes within two miles of San Rafael, crosses the eastern spurs of Tamalpais, and passes by the head of Richardson's Bay to the Golden Gate near Lime Point.

This line has been reconnoitered by the proposers and the levels estimated by the barometer. The length of the whole line is estimated to be 121½ miles. At least four miles will be in tunnels. The character of the country through which the line passes is for the greater part mountainous. The portions of the line not on mountains or hills are those which lie in Napa, Sonoma and Petaluma valleys. It is only in these valleys that the pressure on the pipe will be considerable. In crossing Napa Valley the pressure will be about 700 feet, or 300 pounds to the square inch. Fifteen or twenty miles will probably include all of the line, which will be under considerable pressure. Of the whole length, it is supposed that 100 miles will be upon high or mountainous ground.

Owing to the late date, at which the proposition to use the waters of Puta Creek assumed such form as to justify the Commissioners in taking it into consideration, it has not been possible for the engineer to go over the line. So much of it as could be examined from the traveled roads in two days has been visited, and certain general impressions have been derived which necessarily lack the preciseness which is desirable, and which can only be obtained by a detailed survey, or at least a detailed examination.

As a result of this observation, it is thought that the character and slopes of the hills, and the fact that the route of conduit crosses all the drainage lines of the intervening country—that all of these circumstances forbid any considerable portion of the conduit being canal. It is thought that all or nearly all the conduit must be made of iron pipe. The objections which have been several times mentioned in this Report, as applying to canals aligned on the flanks of the mountains, can be made with force against such an alignment on these hills. If any considerable portion, or indeed any portion of the line be in canal, reservoirs on the route would be essential to keep up the supply, when the canals break.

It is also apparent that the expense of transportation of the pipes through this country will be unusually great, owing to the considerable wagon-haul,

as well as to the roughness of the land. The quantity of iron would, however, be a minimum, owing to the light pressures on the greater part of the line.

Placing the floor of the outlet tunnel at the Coyote reservoir at reference 975, and assuming a height of delivery in San Francisco of 300 feet, we have 675 feet fall from the reservoir to the city. Giving the pipe a fall of five feet to the mile, it will require in 121½ miles 607½ feet, and there will be 67½ feet to spare, which may be made use of to secure a reservoir along the line, which would be almost a necessity under the circumstances. A suitable site is said to exist in the Cañada Pomponio, in Section 12, Township 3 N. Range 8 W., about eight miles south of Petaluma. The capacity of storage in this reservoir is not known.

With a fall of five feet to the mile, it would require a pipe 46 inches in diameter to carry 25 millions of gallons, and one 50 inches in diameter to carry 30 millions of gallons per day.

This question will naturally arise: What further supply of water can be derived from the Northern Coast sources in addition to that derived from Puta Creek? Clear Lake and Cache Creek lie within ten or twelve miles of the Coyote reservoir, and the elevation is abundant to permit the waters from these sources to be stored in the reservoir. Indeed, this reservoir is indispensable for the proper utilization of the waters of Clear Lake. This combination of the two sources would give a drainage basin of quite 600 square miles, which, in connection with the storage capacity that can be secured, would probably yield an abundant supply for all future needs. It is not necessary to recur to the question of quality. This point has been referred to under the head of Clear Lake, and reference to the reports of the various analyses there mentioned is all that is required.

The mountainous country drained by Russian River would also become available, in case the tunnel were constructed. We are, however, absolutely without any accurate information as to the value of this drainage basin for our purposes.

The Tunnel under the Golden Gate will be understood to be an essential feature of this project. Without a safe passage of the Bay the project could not be entertained. With a tunnel constructed from the north to the south shore, the project becomes practicable and worthy of attention. The tunnel itself can hardly be said at present to be either practicable or impracticable. The way to prove it practicable is to build it. The dimensions of the tunnel ought to be sufficiently large to carry quite 100 millions of gallons a day in iron conduits. The width and height to be given to the excavation will be determined by the number and sizes of the conduits.

A profile of the route from the reservoir to the Golden Gate has been prepared from barometric measurements of heights, and from distances estimated by the County and other maps. It was intended to include this

profile in the Report, but upon further consideration, it was thought that the number of points actually determined was too small to justify its insertion.

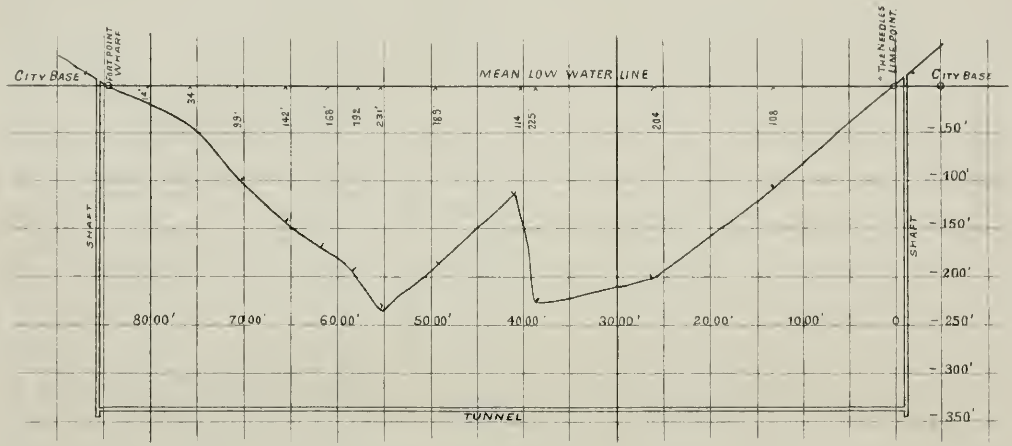
Under these circumstances, it will be understood that it is impossible to present for your consideration at present any estimates upon the cost of constructing this line. Estimates now given would be conjectures, and subject to so large an element of error as to be entirely unreliable.

A general comparison of the route with that from the Mokelumne River indicates some conclusions of value. The length of route from the Mokelumne River, canal and pipe combined, is 175¾ miles. The line from Puta Creek is believed to be less than 125 miles. The difference in length is therefore 50 miles, more or less. The difference in the average weight of pipe must be considerable, owing to the fact that such a large part of the Puta Creek line lies on high ground. On the other hand, the length of tunnels required, and some difficulties of transportation are to be set off against the advantages. It seems quite within the bounds of safety, to express the opinion that the conduit line from Puta Creek, can be built to carry a given quantity of water, very much cheaper than one from the Sierra. It will require $6,000 or perhaps $8,000 to make the surveys, necessary to demonstrate this proposition in a thorough way.

The profile of the tunnel line, proposed by the Feather River Water Company, across the Bay, near the Golden Gate, does not pursue the direct route from Lime Point to Fort Point. This distance is about one mile, whereas the route of the profile is 2,820 yards. The latter lies inside of the former, and the route is adjusted to escape the points where the water is deepest. The deepest water shown on the profile is 231 feet, whereas there is a sounding of 414 feet in the Golden Gate.

The duty which was assumed at the beginning of this report has now been completed. The different projects have been described, their capabilities pointed out, their probable costs estimated, and the circumstances which affect their feasibility stated. These questions and incidental problems have commanded my fullest study and attention for a year and more. The labor which has been bestowed upon them has been made more arduous, by the desire to save the city the expense of instrumental surveys extended over a large fraction of the State. The expense of such surveys would have been very considerable. It was thought possible to bring the general features of the various projects to a fair comparison, with little expenditure for examinations and surveys. To this end the surveys made by my predecessor in 1874 have been of great service. The maps and information derived from the proponents and owners of the various projects have also been of service. Particularly, the surveys and examinations made by the Spring Valley Company have been of value in its own particular field. These have been placed at the service of the Commissioners in a spirit which deserves acknowledgment. When these were all furnished, there remained the labor of comparing, adjusting and recon-

PROFILE of the line of the Tunnel of the Puta Creek line, near the Golden Gate.



ciling discrepancies or clearing up doubtful points of fact, the magnitude of which it can hardly be expected that any one can realize, who has not actually performed it. The principal and determining facts have however been ascertained, and it is believed have been fairly stated. Whatever inaccuracies may exist in statement of facts, they are not such as to affect the main conclusions.

It must be clear that the position and circumstances of San Francisco, as compared with other American cities, are unfavorable for a cheap water supply. It only remains for the people of the city to use their supply judiciously. While there will always be enough for useful purposes, there is none for waste. The supply will doubtless at some future time be supplemented by the use of sea water for the purposes to which it is applicable.

The city has had the faithful services of a number of assistants, among whom it gives me pleasure to notice the principal, I. W. Smith, C. E., who conducted the surveys authorized by the Commissioners with energy and economy, and who afterwards for some months took charge of the office work and estimates.

Respectfully submitted,

G. H. MENDELL,

Engineer of the Water Commission.

San Francisco, Cal., August 6, 1877.

APPENDIX A.

[From Appendix to Municipal Report, 1874-75, Page 55.]

No. 2,371.

State Assay Office, 421 Montgomery Street, San Francisco, April 5th, 1875.

Report of Technical Analyses of seven samples of water received from T. R. Scowden, Esq., Chief Engineer City Water Supply.

WHERE FROM.	Total of fixed Ingredients.		I. Precipitated on exposure to atmosphere at ordinary temperature.		II. Precipitated upon partial evaporation as in steam boilers		III. Remaining in Solution.	
	Parts in 100.000	Grains per Gallon.	Parts in 100.000	Grains per Gallon.	Parts in 100.000	Grains per Gallon.	Parts in 100.000	Grains per Gallon.
Laguna Merced.......	39.40	27.58	9.23	6.461	15.92	11.144	14.25	9.975
Spring Valley	26.60	18.62	6.45	4.515	13.95	9.765	6.20	4.340
Blue Lakes.,...	21.00	14.70	1.66	1.162	17.24	12.68	2 10	1.470
Clear Lakes..........	26.00	18.20	12.75	8.925	10.75	7.525	2.50	1.750
Clear L.—Puta Creek..	16.60	11.62	8.50	5.950	3.85	2.695	4.70	3.290
Calaveras Creek.......	30.60	21.42	16.20	11.340	13.00	9.100	1.40	0.980
Pescadero Creek......	41.00	28.70	20.25	14.175	16.15	11.305	4.60	3.220

Groups I and II comprise the substances which render water hard. I—Consisting principally of carbonates of lime and of magnesia held in solution as bicarbonates. II—Of sulphate of lime (gypsum) with traces of alumina, iron, etc. III—Not precipitable by exposure to the atmosphere or partial evaporation of the water, consists of chloride of sodium and other easily soluble salts.

All the samples naturally contain carbonic acid gas, and more or less organic matter, the latter apparently not of an objectionable character. To determine quality and quantity of organic constituents, larger samples would be required

[Official Seal.] Yours, etc.,

(Signed) LOUIS FALKENAU, State Assayer.

REPORT OF A RECONNAISSANCE OF CLEAR LAKE AND A CHEMICAL ANALYSIS OF ITS WATERS.

San Francisco, Cal., October 16th, 1876.

Hon. A. J. BRYANT— No. 3,838.

President of the Board of Water Commissioners of the City of San Francisco:

Sir—At your request I have made a careful examination of Clear Lake and analyses of samples of its waters.

Clear Lake is a large body of fresh water, the outlet to which is Cache Creek. As far as known it is fed only by small streams which flow into it, and from the rains which fall on a large area of sloping hills during the rainy season.

The geological formation surrounding the lake is cretaceous and recent volcanic. The evidences of ancient solfataric action are conspicuous on every hand. The same agencies are still at work, as may be seen at the remarkable deposit of sulphur and cinnabar known as the "Sulphur Bank." The continual bubbling of gases from the bottom of the lake and the borax lakes are effects from the same cause.

At the Sulphur Bank the evolution of carbonic acid gas is so great that the mines are worked from open cuts instead of tunnels. At the same locality there is an ammoniacal spring described by Professor Whitney in "Geology of California," Vol. I, fol. 99. The water of this spring is remarkable, each wine gallon holding in solution 107.76 grains of Bi-carbonate of Ammonia and 103.29 grains of Bi-borate of Soda.

At Soda Bay, on the margin of the lake, there is a boiling spring of great magnitude, from which the locality is named. The agitation of the water is not caused by heat, as the water is only a few degrees warmer than that of the lake, but by the escape of immense quantities of gases. Near the spring a number of dead fish were seen floating on the surface.

The lake is said to have an area of eighty-two square miles. It is irregular in shape. Although one entire sheet of water, yet different names have been given to different portions of it. The largest portion lying east of Lakeport is known as Middle Lake, while that narrow portion near the exit of Cache Creek is called Lower Lake.

The water of Lower Lake—the first examined—is clear, but contains minute floating substances suspended in it. From the fact that this suspended matter settles and leaves the water perfectly free from it if allowed to stand for some time in a glass, I am led to the opinion that it is held in suspense mechanically by the continued bubbling of carbonic acid gas from the lake bottom.

The water has a decided peaty taste, but not more so that the well water at the town of Lower Lake. I found the temperature of Lower Lake to be 71° F., while that of the air was 78°. The water was carefully examined in a clean white glass bottle, buckets of it being drawn up at short intervals from the deck of the small steamer. Near the exit of Cache Creek there is much vegetable matter growing in the water along the margin of the lake. An arm of the lake branches eastwardly at the junction of Lower Lake and Middle Lake. The water appears somewhat stagnant and a slight scum is seen on the surface which the wind blows into bands. A sample was collected and subjected to microscopical examination. There seems to be no doubt but that it is caused by the bubbly gases bringing microscopical organisms to the surface mechanically. At the easterly end of the bay are the extensive works of the California Borax Company. The quicksilver and sulphur deposit mentioned before as the Sulphur Bank and the hot ammoniacal spring are here. The water of the lake is pumped up through a large iron pipe and used for all purposes, including drinking.

Middle Lake is a large and beautiful sheet of water. The water has less taste than that of Lower Lake, but the quantity of suspended matter seems to be the same. Soda Bay is on the margin of this part of the lake.

Cache Creek is a sluggish stream of about fifty feet in width. The water looks black when seen running in its bed. This is owing to a large quantity of sediment from the water which covers the stones on the bottom resembling a dark colored mud. When examined in a clean glass vessel the water seems clear. There is not nearly so much suspended matter in it as in the water of the lake, but a slight opalescence may be noticed. The earthy taste is more decided, and it is not too much to say that the taste is decidedly bad.

It having been stated that the water of Cache Creek was purer at the junction of North Fork, about seven miles below Fowler Mill, and was free from the unpleasant taste so noticeable at that point, I visited the locality and made a careful examination of the stream and its surroundings. As there is no road along the creek the junction can only be reached by a detour, which I made on horseback. I found the creek running over a clean rocky bed. The water was clear and of good taste, but still having a peaty flavor. The precipitated vegetable matter was much less than at Fowler Mill. In the shallow pools and eddies the same muddy sediment was noticed which I had seen in the creek higher up, but to a less extent. At points where the water ran over a pebbly bottom the stones were clean and the water clear. The creek had the appearance of a mountain stream. There was no water running in the north fork. The parties who acted as guides assured me that the stream I saw was Cache Creek, and that no other stream entered it above. As our route had been a circuitous one I had no way of proving this. In the dry bed of the north fork I noticed an incrustation on the stones, indicating the alkaline nature of the water. By barometer I found that the junction is 240 feet lower than the bridge near Fowler Mill.

I took samples from the following points and sent them to your office by Wells, Fargo & Co., and they were delivered to me at my laboratory with the seals unbroken:

SAMPLE A.—Mud washed from the stones in the bed of Cache Creek.

SAMPLE B.—Water from Cache Creek at Fowler Mill—5 gallons.

SAMPLE C.—Water from Lower Lake taken from the surface—5 gallons.

SAMPLE D.—Water from Cache Creek at junction of North Fork—5 gallons.

SAMPLE E.—Sample from Soda Springs, Soda Bay—½ gallon.

SAMPLE F.—Sample of scum from surface of Middle Lake, near the Sulphur Bank.

SAMPLE A.—Muddy deposit from the bottom of Cache Creek at Fowler Mill. This sample was examined both chemically and microscopically.

CHEMICAL EXAMINATION.

A portion was dried on a water bath. In doing so a strong, earthy or peaty smell was evolved. There is no doubt in my mind but that the water takes its peculiar taste from this deposit.

On incinerating the dried sample it lost (organic)	14.8 pr. ct.
The residue (inorganic) boiled repeatedly in nitro hydrochloric acid left a second residue, (insoluble)	73.0
Soluble portion	12.2
	100.0

The insoluble part was examined microscopically and found to be nearly pure white silica. The soluble portion was largely composed of iron.

MICROSCOPICAL EXAMINATION.

The sediment was found to consist of white silicious fragments and organic life, both animal and vegetable. The most careful examination failed to detect any bacteria or other forms not common in fresh water or that indicated bad water.

Of animal forms the following were identified:

Ciliata=Chætonotus Larus.
Flagellata.
Ova of Entoza.

VEGETABLE FORMS—

Confervaceæ.
Schizonenema in frond.
Paramecium.
Diatomacæ.
" Naviculæ.
" Surirella.
" Nitzschia.
" Mastogloia.
" Cocconeis.
" Encyonema.
" Cocconema.
" Synedra.
" Melosira.
" Cymbella.

SAMPLE B.—Water from Cache Creek at Fowler Mill.

The water was slightly opalescent and had more of the earthy taste than the other samples. A chemical examination was made which showed it to be in other respects like the water of Lower Lake.

A quantitative determination was made of the ammonia and carbonic acid which resulted as follows:

Albuminoid ammonia in 100.000 parts	.03
Carbonic acid, free and combined, in 100.000 parts	7.864

SAMPLE C.—Water from Lower Lake taken from the surface. Water clear, colorless; taste good—only a trace of the peculiar flavor observed at Fowler Mill; reaction slightly alkaline after boiling.

The water contained what appeared to be a considerable quantity of suspended particles, which a microscopic examination showed to be identical with the scum collected on the surface of the lake (Sample F). Although to appearance somewhat voluminous, yet when the suspended matter contained in a wine gallon was collected on a carefully dried filter and weighed after drying on a water bath at 212° F., the weight was inappreciable. This was owing to the impossibility of bringing the filter to exactly the same state of dryness before and after filtering the water. But the experiment suffices to show that the weight of the suspended matter is very small indeed. The ammonia determined by Wanklyn's method was found to be as follows:

Free ammonia in 100.000 parts	.025
Albuminoid ammonia in 100,000 parts	.037
Carbonic acid in 100.000 parts	7.864

On allowing the water to stand for a few hours in a tall cylindrical vessel, every particle of this suspended matter settled, leaving the water perfectly clear.

SAMPLE D.—Water from junction of Cache Creek with North Fork, ten miles below the lake. This water was clear and colorless and was found to contain much less of the suspended vegetable matter peculiar to the water of the lake. Taste good; specific gravity at 65° F., 1.000134; reaction neutral; after boiling, slightly alkaline. Total solids, parts in 100,000, 17.875. The sample was subjected to a careful analysis.

BASES FOUND.	ACIDS FOUND.
Potash, trace.	Sulphuric,
Soda,	Nitric, (trace only)
Ammonia,	Hydrochloric,
Lime,	Carbonic, free and combined
Magnesia,	Silicie.
Protoxide of iron,	
Alumina, trace.	

Organic matter.

When highly concentrated the water effervesced with acids, showing the presence of the carbonate of an alkali. In testing for hardness, the water was found to be remarkably soft.

Temporary hardness (Clark's test)	5 deg.
Permanent hardness	1 deg.
Total	6 deg.

The ammonia was determined by Wanklyn's method and resulted as follows: Free ammonia in one litre, .0002, in 100,000 parts, .02; albuminoid in one litre, .0003, in 100,000 parts, .03. The same result was obtained when the filtered water was subjected to the same test.

QUANTITATIVE ANALYSIS, CALCULATED FOR 100,000 PARTS.

Silica	1.2000
Chlorine	.5063
Carbonic acid	6.2910
Oxide of iron and aluminum	1.2000
Lime	2.2000
Magnesia	2.8000
Sulphuric acid	1.2920
Organic matter, potash, soda (calculated)	2.3857
	17.8750

This sample stood all the tests given by Wanklyn and Chapman for the physical examination of drinking water.

Sample E.—Water from Boiling Soda Spring. This water had a specific gravity at 66° F., 1.0045; solid constituents in 100,000 parts, 51.6. On standing, it lets fall a copious precipitate; when shaken, there is much carbonic acid gas given off. Carbonic acid in 100,000 parts, 39.32. The reaction is acid, but upon being boiled it becomes neutral. A chemical examination showed the presence of the same constituents as the lake waters, but in much greater quantities. Magnesia and ammonia were remarkably abundant, but sulphuric acid gave only traces.

Sample F.—Scum from the surface of Middle Lake, near the Sulphur Bank. This sample was found to consist of microscopic vegetable forms, being mainly composed of many species of living diatoms. It is exactly identical with the suspended matter in the great lake.

The purity of drinking water is a subject to which the attention of chemists and physicians has been specially called within the last few years, and it is considered one of the most important questions of modern science.

The great solvent power of water causes it to take up from substances over which it flows a number of foreign elements, some of them deleterious, others healthful, while still others are inert. It is a wise provision of nature that water seldom dissolves poisonous substances. When it does, they in the course of time become insoluble by coming in contact with other elements, and precipitate.

Organic matter likewise either precipitates mechanically, or breaks up into its elements which are harmless, and which being nearly all volatile, pass from the water to the atmosphere.

The solvent power of water is sometimes increased by the absorption of certain gases. Thus water charged with carbonic acid gas holds in solution large quantities of substances as bicarbonates, which would otherwise be insoluble. When the water parts with the excess of carbonic acid these foreign matters fall. This is why some water becomes turbid when boiled and is the cause of the formation of tufas and deposits left by the waters of mineral springs.

All water has more or less taste. It is unnoticed by those who are accustomed to its use, but is always evident to strangers.

Aside from the question of health there are certain substances sometimes found in fresh water which renders it unfit for domestic use.

Water containing a large quantity of lime or magnesia has a property called "hardness." Perfectly pure water forms a homogeneous compound with soap known as suds or lather. Water which is hard does not produce a lather until a greater or less quantity of soap has used according to the degree of hardness.

There are two qualities of hardness called by chemists, permanent and temporary.

Temporary hardness is caused by the salts held in solution by carbonic acid in excess, and it can be removed by boiling the water. The permanent hardness is that of the water after boiling. For this, distillation is the only remedy. This property of water is estimated by assuming the hardest natural water to contain 16 grains of the objectionable salts in an imperial gallon, (70,000 grains), or the equivalent of 16 parts of calcite or carbonate of lime in 70,000.

Thus water found to contain 9 grains in a gallon is said to possess 9 degrees of hardness. The hardness of water is overcome (when soap only is used), by the actual destruction of a portion of the soap. It has been estimated that twelve pounds of the best hard soap is decomposed and lost for each degree of hardness, before ten thousand gallons of water will be rendered sufficiently soft to combine with more soap and produce a lather or suds.

It is maintained by some that lime being necessary to the normal growth of the human body, water containing it must be healthy, and that absolutely pure water used exclusively in a community would naturally induce disease from the inability of nature to obtain lime for the bones.

On the other hand, Hassall, who is considered the best authority, claims that freedom from lime and in fact all other foreign salts is one of the most important desiderata of water as an article of food.

Hard water is said to produce certain obscure diseases such as cretinism, goitre and calcalus.

The presence of nitrogen is believed to be the most objectionable impurity in water. It occurs in four forms:

1st—Free nitrogen gas.

2d—Oxidized; nitrates, nitrites.

3d—Combined with hydrogen; ammonia.

4th—Combined with carbon, oxygen and hydrogen; organic matter of which albumen is the type.

In the first three forms it is not considered hurtful, but is always sought with the greatest care as being indicative of organic matter in the objectionable form.

The presence of organic matter in water does not necessarily render it unhealthy, as all water contains it in greater or less quantities. The most dangerous contamination of water and the greatest source of evil is sewage. It has been proved that the germs of certain diseases, as cholera, typhoid fever, dysentery, etc., find their way into the human system from the excreta of patients suffering from these diseases, through the medium of drinking water.

Other diseases, such as ague and malarial fevers, are believed to be caused by unknown impurity in marshy waters. Cases are known where communities suffering from these diseases have been relieved by using other water.

Impure water, if left for some time undisturbed, purifies itself of organic matter to a great extent, and at the same time the mechanically suspended impurity precipitates. The organic matter decomposes to its primitive elements, carbonic acid, ammonia and hydrogen.

It is well known that fresh water when first taken to sea undergoes this change, becoming very offensive from the gases evolved. After a time this action ceases and the water is found to be purer and better than when first taken on board. This change goes on gradually when the water is exposed to the atmosphere in large bodies, in which case it does not become offensive during the process of decomposition of the organic matter.

Chlorine although not objectionable in small quantities, the presence of unusual quantities gives rise to suspicion, as salt (chloride of sodium) is largely used in cooking, and would naturally find its way to water contaminated with sewage. In water analysis it is therefore carefully estimated.

There is a great diversity of opinion as to what causes disease in bad water. A few cases are cited in which water pronounced by the best chemists to be pure and wholesome has produced epidemic diseases.

On the other hand, in very many more cases, what the chemist would call bad water has proved a frightful source of disease, and it is believed that in most of these cases the evil is caused by organic matter originating in sewage, or from certain kinds of refuse from manufactories.

The worst waters are those which are turbid and contain the largest quantity of sedimentary matter.

While it is admitted that the presence of organic matter in a certain form renders water unhealthy, the presence of living organic forms, animal or vegetable, should not cause it to be condemned, for no water is free from organic life.

In water analyses it is considered of the greatest importance to estimate the organic matter which is actually in solution. This is done by first estimating the free ammonia present, which is only considered an indication of decomposing organic matter. When the free ammonia is wholly removed the albuminous matter in solution is decomposed by an alkaline solution of permanganate of potassia, and the ammonia resulting from its decomposition carefully determined as albumenoid ammonia. Pure water should contain only traces of ammonia in either form.

There is no natural river or lake water entirely free from ammonia, and it is customary to consider its determination as comparative, it being held that water is good or bad in proportion as it contains more or less of the objectionable compound. Hassall has given the following "standard of purity at which in the supply of water for drinking purposes it is desirable to aim:"

Mineral matter in 100,000 parts	14–17
Free ammonia " "	0.005
Albuminoid ammonia in 100,000 parts	0.10
Temporary hardness	10.
Permanent "	2.

That they may be compared, I place here the same items from the analysis of Sample D:

Mineral matter in 100,000 parts	17.875
Free ammonia " "	.025
Albumenoid ammonia in 100,000 parts	.037
Temporary hardness	5.
Permanent "	1.

It cannot be denied that Clear Lake is a remarkable body of water, which can scarcely be compared with any other of which we have any knowledge. It will be seen by referring to my observation at the lake and by the analysis of the samples placed in my hands, that pertaining to the lake and its waters there are several peculiar features.

1st—The solfataric action, causing the bubbling of gases from the bottom of the lake, and the two remarkable ammoniacal springs. It is safe to assume that there may be others of a similar nature beneath the waters.

2d—The suspended vegetable matter.

3d—The peculiar taste of the water more marked at Fowler Mill.

4th—The dead fish.

Solfataric action is caused by chemical changes going on beneath the earth's surface. It is not believed to be necessarily deep-seated. It is from the same or similar causes that our deposits of cinnabar and other minerals are formed. It is not necessary to allude to the theories as to the causes of solfataric action. It is sufficient to state that it shows it-

self over a large portion of the Pacific States, and that carbonic acid and other gases are freely evolved at many points where they can force their way to the surface.

Ammonia is rare, but it is found in volcanic regions, notably at Vesuvius, Hecla and Mauna Loa, in the form of the chloride. Professor Whitney thinks the ammoniacal spring described in his report as without a parallel, as it holds more ammonia in solution than any other natural water known.

Carbonic acid is to vegetable life what oxygen is to animal life. Plants under the influence of sunlight decompose, carbonic acid absorbing the carbon and setting the oxygen free. Ammonia is also food for the plants, furnishing nitrogen, which they require.

Warm sunlight and water charged with carbonic acid and ammonia could scarcely exist without vegetable life. It is thought that the luxuriance of vegetation during the carboniferous age was caused by the excess of carbonic acid in the atmosphere at that period, and the vegetation was instrumental in locking it up in the coal deposits, before which the higher order of animal life could not exist. Similar conditions exist at Clear Lake, which I think accounts for the abundance of vegetable matter in the water.

The gases not only act chemically but mechanically, to which I have before alluded, keeping the minute vegetable matter suspended by the agitation caused by the bubbles rising to the surface.

My experiments in Sample A have shown that the peculiar taste arises from the muddy deposit. It is more apparent in Cache Creek, where the deposit is larger. This might be remedied by cleaning Cache Creek, or by taking the water from the centre of the lake. My theory as to the dead fish is that they are killed by inhaling water highly charged with carbonic acid gas in the near vicinity of the great spring at Soda Bay.

In making this report I have been careful to state the true results of my observations at the lake and my examination of the different samples, so that others may form an opinion as well as myself. In view of the diversity of opinion as to what constitutes a water suitable for the requirements of a great city, I think the judgment of as many chemists and physicians as possible should be solicited. As for myself, I am of the decided opinion that the water is good, being suitable both for domestic use and for manufacturing purposes—better, in fact, than that furnished to most cities in the world.

I have accounted for the presence of ammonia, and have shown that this and carbonic acid stimulate vegetable growth. Remove the cause by seeking a reservoir sufficiently remote from the solfataric action known to exist at the lake, and the vegetable matter will precipitate. The ammonia which is no doubt in form of the bi-carbonate, will break up into its elements and escape to the atmosphere. The excess of carbonic acid will also pass to the air and a pure healthy water remain. Respectfully,

[SEAL.] HENRY G. HANKS.

APPENDIX B.

PROPOSITION OF THE LAKE TAHOE AND SAN FRANCISCO WATER WORKS TO SUPPLY THE CITY AND COUNTY OF SAN FRANCISCO WITH PURE, FRESH WATER. SUBMITTED TO THE HONORABLE, THE BOARD OF WATER COMMISSIONERS.

SOURCE OF SUPPLY.

Lake Tahoe, the main source of supply of the Lake Tahoe and San Francisco Water Works, is located in the Sierra Nevada Mountains, at an elevation of about 6,220 feet above sea level, and covers an area of some 240 square miles; its greatest depth being about 1,500 feet.

The quality of the water is, beyond doubt, the purest in the world, being produced by melting snows and mountain streams, the enclosing and surrounding mountains being mostly of granite formation, and having a watershed estimated at 500 square miles. The only outlet of the Lake is the Truckee River, which flows during the driest seasons of the year 800,000,000 gallons of water per diem, and for some months during the floods more than three times that quantity.

To guard against dry seasons, a dam has been constructed by the Company on the Truckee River, at the outlet of the Lake, with suitable gates, for the purpose of storing the water, by preventing the usual floods escaping out of the Lake and running to waste, at the same time allowing the necessary amount of water to flow down the Truckee River for the use of mills and manufactories. The Lake will fill to the capacity of this dam in one ordinary season.

The quantity of water thus stored will be immense, and can be better understood and appreciated by stating that one foot of water drawn from the Lake in a whole year would give a daily yield of 137,000,000 gallons.

The Lake has been raised by said dam some six feet above low water mark, or about one foot above high water mark, and it will now give six times 137,000,000 or 822,000,000 of gallons per diem, without interfering with the natural or ordinary flow of the Truckee River, that is, with the Lake filled up to the full capacity of the dam.

A second dam has been constructed on the Truckee River, at a point 3¾ miles below the dam at the Lake, at which second dam the water is diverted from the river and taken into a canal.

Independent of the Lake, there are several creeks or streams which the Company can draw water from during the rainy season, and while the snow is melting in the spring of the year, namely, Bear Creek, Squaw Valley Creek, Deer Creek and Hardscramble Creek, all of which are on the east side of the mountains and are tributaries of the Truckee River below the Lake.

On the west side of the Sierras the Company avails itself of several tributaries of the American River, which afford quite a large supply of water in the spring and early summer months. It will therefore be seen that water from Lake Tahoe need only be drawn when these streams fail to supply the amount of water required, and it is estimated that the Company, or others using the water, would only require to draw from the Lake about eight months out of the twelve. The water in these feeders and tributaries is of equal quality with that in the Lake.

TITLE.

The Company's title and ownership to the waters, and right of way, is acquired and confirmed under and by virtue of the Incorporation laws of the State of California, and by an Act of Congress of the United States, passed July 25th, 1865, entitled, "An Act granting the right of way to ditch and canal owners, over the public lands, and for other purposes."

At the second dam, heretofore referred to, the Company own by location and purchase from the University of the State of California, the southwest quarter of section 34, Town-

ship No. 16 North, Range No. 16 East, Mount Diablo Meridian, located in Land Office of the United States, for California, August 6th, 1870. This location embraces the bed of the Truckee River for the distance of one-half mile.

The Company also owns by location and purchase, in the same manner, the south-east quarter of section Eight, Township No. 16 North, Range No. 15 East, Mount Diablo Meridian, located August 25th, 1873. This location is on the west side of the Sierra Nevada Mountains, and covers one-half mile of the South Fork of the North Fork of the American River, and is near the outlet of the projected tunnel of the Company through the mountains. At this place the Company have constructed good buildings for offices, workshops and quarters.

LINE OF WORKS.

To make the waters of Lake Tahoe available, the following work is necessary to be done, viz.:

The water passing from the dam at the outlet of the Lake will flow down the Truckee River three and three-quarter miles to the Company's second dam on said river, at which point it is diverted from the river into a canal, thence along said canal a distance of fifteen miles to the entrance of a tunnel through the Sierra Nevada Mountains. The water from said canal enters and flows through the tunnel, coming out on the west side of the mountains, at a point a short distance above Soda Springs (so called), on the South Fork of the North Fork of the American River, beginning at the head of Cold Stream, surveyed for railroad and water tunnel, which is (24,172) twenty-four thousand one hundred and seventy-two feet long, with an open cut of a quarter of a mile long, and average depth of ten feet. To reach the entrance of this tunnel, it would require fifteen miles of canal from said second dam on the Truckee to the entrance of the tunnel or cut.

The first 5,676 feet of the tunnel can be worked out through several shafts of 100 feet in depth, leaving 18,496 feet to be worked from two faces, a distance less than three and a half miles, on a grade of forty feet to the mile, if required.

The track of the Central Pacific Railroad Company runs within a few hundred feet of the proposed shaft for tunnel on the east side of the mountains at the head of Cold Stream.

The line of the works from the tunnel would be as follows:

The water, after leaving the tunnel at or near Soda Springs, on the west side of the mountains, would flow down the granite bed of the American River about twelve miles, where it will be diverted from the river and conducted in a suitable canal a distance of about sixty miles to a point near Dutch Ravine, in Placer County, at which point it will enter a reservoir of convenient size. From which point to San Francisco the water will be conducted in wrought iron pipes.

SURVEYS.

Careful and elaborate surveys have been made of all that part of the line of works from Lake Tahoe to the tunnel line, and across the mountains to the western terminus of the tunnel.

The Central Pacific Railroad Company has run a survey from the terminus of the Cold Stream route down the American River, on a grade of eighty (80) feet to the mile, to a point at Dutch Flat, making actual distance from Soda Springs to that point, forty-two miles; the remaining distance to Dutch Ravine is estimated. In all, it would be about sixty miles by canal.

The elevation of the tunnel on the west side of the mountains is 6,143 feet above base.

It has been proposed by the Water Engineer, Col. Mendell, that the site for the reservoir be changed from Auburn to Dutch Ravine, near New Castle, on the Central Pacific Rail Road, which gives an elevation of 880 feet above city base. Diameter of pipe, 43.75 inches; length of pipe, from Dutch Ravine Reservoir to San Francisco, 122.44 miles, and discharging at an elevation in San Francisco of 300 feet above City base, 20,000,000 gallons in 24 hours.

The capacity of the canal to Dutch Ravine Reservoir will be 100,000,000 gallons per day.

DISTANCE FROM LAKE TAHOE TO DUTCH RAVINE RESERVOIR, NEW CASTLE.

From Lake Tahoe to 2d dam in bed of Truckee River	3.75	miles.
Length of Canal from 2d dam to Cold Stream Tunnel	15.00	"
Length of Tunnel, Cold Stream route	4.57	"
Down bed of American River	12.00	"
Canal from American River to Dutch Ravine	60.00	"
Total distance	95.32	"

Ninety-five and thirty-two one hundredths miles.

The line of works from the Dutch Ravine Reservoir will be *via* Sacramento, Fairfield, Benicia, Oakland and San Francisco.

From Reservoir Dutch Ravine to San Francisco (Pipe)	122.44	"
Total in miles from Lake Tahoe to San Francisco	217.76	"

ESTIMATED COST.

Canal East of Sierras, 15 miles, at $25,000 per mile	$ 375,000
Tunnel through Sierras (8 feet circular) 24,172 feet, at $50 per running foot	1,208,600
Stone dam on American River	50,000
Canal lined with stone, where required, estimated distance 60 miles, at $30,000 per mile	1,800.000
120 miles fencing, at $600 per mile	72,000
Two miles of 5 foot ¼-inch pipe for crossing Ravines	100,000
Reservoir Dutch Ravine	450,000
Wrought Iron Pipe from Dutch Ravine Reservoir to San Francisco, 122.44 miles, in accordance with Engineer's Specification, 110.971,801 lbs., at 4½ cents per lb. (or 55,485 tons)	4,993,731
Rivets, making and laying same, $5 per foot	3,235,055
Transportation, $5 per ton	277,425
Tunneling Straits of Carquinez	350,000
Crossing Bay San Francisco with submerged pipe (ball and sockets)	500,000
Air Valves, gates, and extras	100,000
	$13,511,811
10 per cent. Contingent	1,351,181
Franchise and Water Rights	300,000
Total Cost	$15,162,992

If it should be required to construct a pipe to carry 30,000,000 gallons per day, it can be done for an additional cost of $3,291,514, or $18,454,506, which amount of water would be required by the time the works could be completed.

The making of the pipe should be near the line of works, as well as the dipping in asphaltum, which will save expense in hauling and scaling of asphaltum.

To cross the Straits of Carquinez I sink a shaft on each shore to a proper depth, and thence tunnel under the bed of the Strait until the two tunnels meet, when I lay my pipe and let the tunnel fill with water. It becomes simply a mining operation. For this work I estimate, in addition to cost of pipe, $350,000, the distance being about three-fourths of a mile. Thence the line will pass in the direction of Oakland, through San Pablo Valley, and will probably discharge into a reservoir back of Oakland, at an elevation 400 feet above base. Thence the line I propose to follow is to the Encinal, Alameda. Thence across the Bay to San Bruno Mountain or its vicinity (which method I proposed as early as October 1st, 1871, as well as crossing the Straits of Carquinez).

CROSSING BAY OF SAN FRANCISCO.

propose to cross the Bay of San Francisco in the foll wing manner:

1.—I drive two rolls of piles in pairs, six feet apart one way and one hundred feet apart the other way, across the Bay, from shore to shore. I put the pipe together on a small railroad on the Alameda shore, the outer end thereof being closed up; as fast as I put the pipe together I float it out on the surface of the water in a line between the two rows of double piles, where it remains; section after section is so added until the pipe reaches from shore to shore. While this pipe is being so floated across the Bay, an air pressure is kept thereon to prevent water from the outside filling it before the whole distance across the Bay is laid. When the pipe is ready to be lowered I stop the air supply and gradually fill the pipe with water, which will cause it to sink to the bottom of the Bay, and soon form its own bed; the pipe being guided by the double row of piles on either side will of course settle down in a straight line; all the pipes will have flexible joints, which will permit them to form a considerable angle without breaking or leaking.

This method has been successfully used in crossing the Schuylkill River, at Philadelphia, (See annual report of the Chief Engineer of the Water Department of the City of Philadelphia, presented to the Council February 16th, 1871, on page 14), which says: "This plan was patented by Mr. Jno. F. Ward, of Jersey City. A contract was accordingly made with that gentleman, and the main has been successfully laid. It is thirty-six inches diameter, has a movable joint of simple and peculiar construction, which admits its being sunk length after length from a scow, by suitable skids and derricks.

The inside of the bell of the pipe is turned smooth to a spherical form, the small end of the pipe has grooves in it to retain the lead when the pipes are put together, a lead joint is cast and caulked in the ordinary way. The smoothness and form of the inside of the bell permits the requisite motion, the lead joint slipping upon that, while it is retained firmly by the grooves in the small end of the pipe.

I state the above to prove that the laying of submarine pipes has already been successfully accomplished; however, I am of the opinion that my plan of floating the pipe out from the shore is better than that of laying it out of a boat or scow.

From the end of this pipe the water will be conducted to a reservoir constructed by the City, at an elevation of 300 feet above base, and from thence distributed throughout the City.

CITY SUPPLY AND WANTS.

In regard to the city's future wants there can no longer be a doubt of the future growth of this City as a fixed fact. It can be almost fixed with mathematical accuracy that this city will have a population of 500,000 inhabitants in ten years hence. No calculation for this City should be made at a capita or person for all purposes less than 100 gallons per day. In regard to this quantity we have only to look to the City of New York. The City of San Francisco has no rains of any amount in the Summer months as New York. Therefore, it is my opinion, as an engineer, that no water supply from the mountains should start with a less supply than will furnish 100 gallons to each inhabitant.

It must also be recollected, that Lake Tahoe will and can furnish water for mining purposes, in addition to that required for cities and towns; carrying 500,000,000 gallons per day through the tunnel into the South Fork of the North Fork of the American River, thence 100,000,000 to the reservoir at Dutch Ravine.

SALE OF WATER AND REVENUE.

From the sale of water for mining purposes, the driving of factories along the line of Railroad, the furnishing of the different towns and villages along the line of works before it reaches the City of San Francisco, will produce an income that will pay the entire interest on the bonds to be issued to construct the works.

No one can question the quantity or quality of the "Lake Tahoe" water; a grand reservoir, located at an elevation of 6,220 feet above the sea, covering an area of nearly 240 square

miles, with a depth of 1,500 feet, surrounded by high granite mountains, covered with beautiful pines, firs and other mountain growth, for beauty it has no equal in this State or any other. The water that supplies the lake is derived from innumerable mountain springs and the melting snow, which falls to a great depth in the winter months. It has no filthy drainage and can never have. I will state that the estimate of the strength of the iron pipe, as required by the Water Engineer, is extra heavy, and, therefore, has increased the cost of the work over my former estimates; still, it is to the City's interest that the pipe be stronger than absolutely necessary.

The Lake Tahoe and San Francisco Water Works will contract to do the work in accordance with the written specifications furnished by Col. Mendell, and perform the work in the best workmanlike manner, and to the Engineer's satisfaction.

Time required to complete the work is five years from the time of signing contract.

Seventy-five per cent. to be paid as the work progresses, balance on completion of contract. Estimates in U. S. gold coin.

All of which is respectfully submitted.

A. W. VON SCHMIDT,
President Lake Tahoe and San Franciaco Water Works.

February 14th, 1877, and
June 14th, 1877.

EL DORADO WATER AND DEEP GRAVEL MINING COMPANY.

To the Board of Commissioners for Water Supply for San Francisco:

In behalf of the El Dorado Water and Deep Gravel Mining Company I beg leave to submit a general description of the water rights which it is proposed to offer the city, and also an outline of the works to be constructed to deliver the water within the corporate limits.

These rights consist of the entire watershed of the south fork of the American river, in El Dorado county, and the drainage therefrom of the main stream and its various tributaries, and the summit lakes which feed them. The watershed aggregates some 500 square miles, 350 of which lie above the point at which it is proposed to divert the water, and embraces all the lakes of which the drainage ground supplying them directly is something less than 120 square miles.

Upon the south fork we own, by denouncement and appropriation, two rights. One, at Cedar Rock, the head of our present main trunk canal, of 20,000 miner's inches, or something over 380,000,000 gallons daily; and the other, at the head of the old south fork canal, of 15,000 miner's inches, or over 285,000,000 gallons. These rights were originally acquired under the various laws of the State and of the United States, concerning the denouncement and appropriation of water, the granting of rights-of-way for canals, and of reservoir sites. They were taken up by several different companies, mainly between the years 1850 and 1857, who constructed in the aggregate some 144 miles of ditches for mining and irrigating purposes, at a very heavy expense. These various rights and improvements were acquired by purchase and consolidated by the present company some three years since, and have been greatly extended by the present owners.

The summit of the Sierras embraced within this watershed varies in elevation from 8,000 to 10,000 feet above sea level, and from 4,000 to 6,000 feet above the bed of the south fork, which, from Strawberry, falls on an average about 90 feet to the mile. From an elevation of about 6,000 feet to the summit, the snow-fall usually varies from 10 to 25 feet in depth, and remains until midsummer, and not unfrequently, on the more elevated points, through the entire year.

From the great extent of this watershed, the heavy rainfall and depth of snow which feed it, the supply of water to the south fork is so immense in all ordinary years, and even

for three-fourths of dry years, that it is needless to dwell upon its capacity as a source of supply, except in periods of extreme drought.

Mr. F. A. Bishop, the engineer of this company, from an observation of over twenty years, estimates that the south fork will gauge, on an average through the year, 50,000 miner's inches, or nearly 1,000 millions gallons daily. But, as I have said, it is useless to dwell upon these statements of the ordinary supply. It is simply beyond all the conceivable requirements of this or any other city, and it is only necessary to examine its resources in exceptional dry years.

And here I beg leave to invite your special attention to what we regard as the distinctive feature of this scheme—unapproached by any other, on the Western slope at least. It is the series of magnificent lakes lying along the summit of the Sierras, within our watershed, and embedded in almost perpetual snows. I will only here state the approximate watersheds and storage capacities, when dammed, of the six principal lakes:

SILVER LAKE.

Watershed	50 square miles
Height of Dam	30 feet
Area of water surface	2,500 acres
Gallons stored	25,000,000,000

Daily supply of 100,000,000 gallons for 250 days.

TWIN LAKES.

Watershed	20 square miles
Height of Dam	20 feet
Area of water surface	1,500 acres
Gallons stored	10,000,000,000

Daily supply of 100,000,000 for 100 days.

ECHO LAKE.

Watershed	11 square miles
Height of Dam	75 feet
Area of water surface	2,500 acres
Gallons stored	61,000,000,000

Daily supply of 100,000,000 gallons for 610 days.

MEDLEY LAKES.

Watershed	12 square miles
Height of Dam	20 feet
Area of water surface	3,600 acres
Gallons stored	23,000,000,000

Daily supply of 100,000,000 gallons for 230 days.

GLACIER LAKE.

Watershed	15 square miles
Height of Dam	20 feet
Area of water surface	2,000 acres
Gallons stored	13,000,000,000

Daily supply of 100,000,000, gallons for 130 days.

AUDRAIN LAKE.

Watershed	8 square miles
Height of Dam	25 feet
Area of water surface	700 acres
Gallons stored	6,000,000,000

Daily supply of 100,000,000 gallons for 60 days.

Recapitulating the essential items of these statements, we have, of the 350 square miles of watershed lying above the point of diversion, 116 square miles which shed their waters first into these lakes, giving an aggregate area of water surface to them of 12,800 acres, or 20 square miles, and affording a storage capacity of 138,000,000,000 gallons. Reducing the cube of this volume of water by thirty-five per cent., and we still have left 90,000,000,000 gallons; which is adequate to a daily supply for one year of something slightly under 250,000,000 gallons, or a supply of 100,000,000 gallons daily for two years and six months; or a supply of 100,000,000 gallons per day for four months of the year (probably the longest time it would ever be necessary to draw from them) for seven years, without annual replenishment.

In addition to these magnificent natural reservoirs there are numerous smaller lakes, and a large number of sites for artificial reservoirs on the declivities of the watershed, probably aggregating in capacity twenty-five per cent. of that of the lakes. The most prominent of these sites I have indicated, in red, upon the map before you. But it would seem a useless task of piling Pelion upon Ossa to dwell longer on this question of adequacy of supply. Before leaving the subject, however, I would draw your attention to the important difference in point of reliability between a snow and a rain fall. There are so many physical and meteorological conditions which affect the question of catchment, that, as yet, hydraulic engineers and meteorologists have been unable to establish any fixed relation between the rain fall and actual catchment, and have found it necessary to discard annual averages, though extending over long periods of time, and assume the minimum of consecutive dry years as the only reliable basis of supply. It is a well known fact that the percentage of actual catchment depends almost wholly upon the character of the rain fall, whether it be gentle and intermittent and is lost by absorption and evaporation, or the contrary. And observation here teaches us that in extreme dry years we are not only short in quantity of rainfall, but from the character of the rains, a smaller percentage is available for catchment. But no such uncertainty attaches to a snow fall. It lies where it falls, and whether it be gentle or violent, is not a factor in the question of catchment, as in the case of rain, which must be utilized at the moment or not at all. We have had many seasons here when, not only all of our coast range and foot-hill sources of water would have been entirely inadequate to the supply of a large city, but even our mountain streams, from their natural flowage, would have failed to supply it, but no such thing has ever occurred as a failure of snow fall amply sufficient to fill these great natural reservoirs—thus placing the supply far beyond any conceivable demand or contingency. I shall have occasion to refer briefly to this subject again.

With this general statement as to our sources of supply, I will now propose to state what is proposed to be done to introduce the water into the city. We propose to take the water from the south fork of the American River at the present head of the old south fork canal, built in 1851, which has an elevation of something over 2,500 feet above sea level. We will from this point construct a canal with a capacity of delivering 100,000,000 gallons daily, substantially along the line of the old south canal, to a point about three miles from Placerville, known as Negro Flat, a distance of 24 miles from the head. Here a reservoir of about 200 acres in area will be constructed, with a dam 80 feet high, which will have a storage capacity of about 3,000,000,000 gallons. This has not been required by your engineer, but is suggested by us for the reason that it is already commanded by our main trunk canal, which takes its water at some 1,500 feet higher elevation, and is of equal capacity, which would not only be an additional guarantee against any interruption of supply, but with comparatively small additional cost would deliver 200,000,000 gallons daily at the head of the pipe line. From this reservoir the water will be again taken in open canal some 18 or 20 miles via Diamond Springs, Mud Springs and Shingle Springs, the present terminus of the railroad, to a point near Latrobe, which will be the head of the pipe line. At this point another reservoir will be constructed of about 400 acres in area, at an elevation of some 1,350 feet above sea level, with a dam 85 feet high, and which, at an average depth of 50 feet, would contain over 6,500,000,000 gallons. The total length of the canal

will thus be something under 45 miles, and will be paved with rock wherever required, and inclosed on both sides for its entire length with lateral drains on the upper bank, so as to protect it absolutely from all contamination. It will be observed that the canal will take its water from the main stream at a point below the confluence of all of its various tributaries, which are fed by the lakes heretofore described, and will be supplied by a watershed, including these lakes, of some 350 square miles.

From the Borland reservoir, near Latrobe, the water will be taken in a 40-inch iron conduit by an air line, a distance of 83 miles to another reservoir at Livermore Pass, of about 738 feet elevation. From this reservoir it will be again taken by a pipe of 42-inch diameter to the neighborhood of Niles' Station; thence around the head of the bay on solid ground; thence through Santa Clara and San Mateo counties to the city limits, a distance of 74 miles, making the total length of the conduit 157 miles. It is to be buried the entire distance two feet under ground, and will deliver 20,000,000 gallons daily. All the work is to be done according to the specifications and under the general supervision of your own engineer.

Such is a general outline of water rights owned by this company, which it is proposed to sell to the city, and the work to be done to supply the water. Having given this statement, I am now expected, as I understand the object of this meeting, to state further, for the information and benefit of the public, what are the particular advantages possessed by this scheme. Having visited this property yourselves, in company with your engineer, I would gladly leave the subject without a comment, having the most entire confidence in the honesty of purpose by which you will be actuated in your recommendations, and feeling equally assured of the superior advantages which our scheme possesses. But as it is not to be supposed that you are to champion any scheme, I shall have to beg your indulgence, if, for the benefit and information of others, I have to state many facts already familiar to yourselves. They will be found, however, to be such as pertain to every thorough investigation of water supply, and are mainly the result of the very exhaustive researches which have taken place upon this subject in various parts of the world within the last ten years.

I may state succinctly the advantages which we claim for this scheme are—

First. The adequacy of supply under all conceivable conditions and contingencies, present or prospective.

Second. The economy of maintenance due to the advantages and facilities for supplying other large and growing communities *in transitu.*

Third. The important hygienic properties of the water, due to its great purity and freedom from contamination.

After what has been said regarding the extent of our watershed and the storage capacity of our lakes, it is unnecessary to say anything further under that head, and it only remains for us to examine some of those phenomena of the supply and consumption of water, which have been developed by the growth of all great cities, to understand what may be those extraordinary emergencies to which we may be at some time subjected, and against which it is important to provide.

It appears from investigation that every important town and city, without exception, so far as I have been able to discover, has found that not only has the actual consumption greatly exceeded the estimate and has increased in a more rapid ratio than that of population, but that the supplies, especially those depending upon catchment, though based upon the average of rain falls for long periods and cycles of time, have fallen far short of the original estimate. I may mention as illustrations of this fact that in 1850 the City of London consumed only 44,383,332 gallons per diem; in 1856, only six years later, it used 81,000,000; and in 1865, 108,000,000. In 1854 Philadelphia consumed something less than 12,000,000, which had risen in 1874 to over 42,000,000. New York, in 1850, consumed about

18,000,000, whereas in 1876 the consumption was over 88,000,000, and even with its boasted Croton Works, a water famine became imminent.

There are no physical or climatic reasons why we should be exempt from the meteorological phenomena which periodically occur elsewhere. But upon the contrary, it is a question whether we are not even more liable to these occurrences than other localities upon the one hand, and upon the other, require a greater amount of water per capita than any other community in the world. From the thirsty character of our public grounds—the limited rain fall, the numerous private gardens, the universal custom here of building even the humblest dwelling with bath room and closet—the high prevailing winds filling the atmosphere we breathe with pulverized animal fæces and fungoid matters, containing the very germs of disease. Were our sewers properly flushed, our streets sprinkled, our sand-doons converted into parks, and those existing beautified with lakes and fountains, as is proposed, we should to-day be using 20,000,000 gallons per day instead of 12 or 13,000,000.

It is well known that our catchment season here is practically confined to four months of the year. We all know what were the results of the extraordinary seasons of 1850–51, 1862–63, 1863–64, 1868–69, 1869–70, 1870–71, and the one which is now upon us, to say nothing of 1827–28, when, I have been credibly informed, there was no rain here for over eighteen months.

It is unnecessary to comment upon these facts, as every one can understand what would be the result of these occurrences when this community shall have attained a population of a million inhabitants, which is inevitable at no very distant day in the future. The grave question then arises, whether all of our theories as to a water supply by catchment from the coast range and foot hills are not wholly fallacious, when tested by these extraordinary occurrences. At Greenwich it required meteorological observations of over fifty years to develop the phenomenon of five consecutive dry years, all below the average of the cycle. And according to that law of inevitable averages, we have every reason to expect the re-occurrence here of these extraordinary droughts. In closing this branch of the subject I cannot resist referring to the result of its investigation in other quarters, and which would seem to more than confirm such apprehensions. In 1868, Mr. John Taylor, the assistant of Mr. James Simpson, Engineer to three of the London water companies, at the request of the eight companies supplying that city, visited all the principal cities and towns of England and also Glasgow—the best supplied city in the United Kingdom—to ascertain what had been the effect upon their water supplies of the extraordinary drought of that year. He visited over twenty of the most important ones, including Manchester, Liverpool, Sheffield and Newcastle. He found, without exception, that the supplies had all fallen far short of the catchment originally estimated, and in nearly every instance they had erected or were about to construct pumping works to supply the deficiency.

He had opportunities of reviewing an immense amount of data in the various localities, extending over long periods of time, as to the rainfall and the theory of averages upon which the various works had been constructed. After referring in detail to the various cases, he forcibly concludes by saying:

"Manchester and Glasgow are favorable examples of gravitation works, but exhibit signs of deficiency when tested by cycles of dry years. * * * * The axiom in mechanics that the strength of a beam is the strength of its weakest part, applies also to gravitation works, their strength or power of supply being only the minimum quantity they may be reduced to. * * * The general result has been that nearly all gravitation supplies of water obtained from drainage grounds have failed in a manner hitherto unprecedented within the known experience of such works, proving that the data on which they have been based have been fallacious."

If, then, such has been the result where the opportunities for observation have been so superior to ours, we certainly have no right to expect to escape similar or even more disastrous results. Assuming that our consumption will at some day reach 100,000,000 gallons per diem, and assuming that we had a gathering ground of 200 square miles, and reservoirs of 3,000 acres of 50 feet average depth, storing 48,877,650,000 gallons, and allowing evapora-

tion to be six inches per month—if we test this assumed capacity, though far exceeding anything we actually have, by the supply of 1862–63 and 1863–64, commencing on the first of April, 1862, with reservoirs full—and allowing 50 per cent. of the rain fall to be utilized by catchment, and we should run entirely out of water before the first day of April, 1864, and from that time until November following would not have one drop. But I am satisfied that my estimates are entirely too liberal, and that not over 25 per cent. of the rain which fell in those two seasons would have been utilized. By the same test, the three dry seasons ending in 1871, though averaging 18 inches, as against less than 12 for 1862–63 and 1863–64, the result will be found to be still more disastrous, and we would have been entirely out of water before the rains of 1871 ceased.

Now, if I understand the scope of your duties and your desires in the premises, it is to settle this water question, not only for the present, but for a l time to come. And if, in the light of these facts, it is evident that at some future day the necessity will arise of going to the mountains for an adequate supply, I think there can be no difference of opinion as to the policy of doing so now, when you can acquire that supply for one-half the amount you will in the mean time expend upon some inadequate source, which may be nearer at hand. And as there is no mountain source possessing the abundance of water owned by us that can be obtained at anything like the same cost, it follows as a logical conclusion that the purchase of this scheme is pre-eminently the thing for you to do.

I now come to the question of distance and the cost of maintenance. This is a favorite objection with those having foot hill schemes for sale. But I may inquire, if you have not got the necessary amount of water nearer at hand, "What are you going to do about it?" But in point of fact there is nothing in the objection, if, in reality, it is not an actual advantage. The engineering is perfectly simple, and it is only a question of dollars and cents. I will only mention here, while passing for the benefit of those for whom "distance" seems to have no "enchantment" when applied to water projects, that of the five principal schemes presented to the Royal Commission for the supply of London, and advocated by the very first engineers of the kingdom, the shortest one was 135 miles, and from that up to 240 miles, as in the case of the Cumberland and Westmoreland Lakes. And a prominent feature in this latter scheme was the supplying of some twenty odd other cities and towns, *in transitu*, consuming some 130,000,000 gallons daily, which is one of the advantages which we claim for our scheme. As before stated, we propose to bring to the reservoir at Latrobe 100,000,000 gallons by open canal, while the pipe line will only take, for the present, 20,000,000 daily. This pipe line, as will be observed, passes through the Sacramento, San Joaquin, Suñol and San Jose valleys, and in the immediate vicinity of Stockton, the various railroad stations, and at Niles', in convenient distance of Oakland and Alameda and intermediate villages and stations; also, by San Jose, Santa Clara, Fairfield, Menlo Park, Redwood City and San Mateo. If, now, California has anything like the future we all believe it has, all these valleys and inland towns and villages will greatly increase in population, and before a second pipe line will be required, these places cannot aggregate much less than 500,000 people, consuming, perhaps, 20,000,000 gallons of water daily. Now, 20,000,000 gallons at 25 cents per 1,000, in ten years amounts to over $18,000,000, or more than enough to construct the entire line; and so on for every future line it may be necessary to lay. So far as the canal is concerned, this company will gladly undertake to maintain it and keep it in thorough repair for the excess of water it will carry until such time as the City may require it. So far, then, as the distance is concerned, it is an actual advantage, if properly utilized, and will ultimately become an important source of revenue instead of an expense, and thereby reduce the cost of water to the consumers of the city.

In this connection it may not be impertinent to mention here what now seems to be conceded as a matter of policy in all schemes of water supply to cities, and that is, water should not be taken for such purposes from districts where it is, or may become, necessary for local use. In this respect, we again present an advantage, as the water which we propose to bring is only that which now runs to waste, but which we would impound by damming the lakes heretofore described.

I now come to the last, but by no means the least, advantage which this scheme possesses, and that is, the great purity of the water and its value as such in a sanitary point of view. But few, indeed, outside of professional men, understand the real importance of this branch of the subject. It has, fortunately, undergone the most exhaustive investigation within the past ten years, by many of the most eminent physicians, hygienic chemists and hydrologists, and there is an immense mass of evidence now accessible to all upon this important subject.

In the elaborate examination of the Royal Commission on Water Supply of London, already referred to, much valuable, if not startling information, was elicited. From the testimony taken by that Commission, the great importance of procuring water which was not only pure at the source, but which should not be contaminated in transitu, was abundantly shown. They went elaborately into the question of the character of the watersheds and gathering grounds and the geological formation of the intervening country, as well as the probabilities, from the nature of things, of such changes in the industries of the country that might lead to contamination in the future. There was a vast amount of testimony taken from every scientific man of any eminence who had bestowed attention upon the subject. The weight of this testimony goes to show that every scheme that derives its water from highly mineralized districts, or where the gathering ground, or intermediate country, is employed for pasturage or agricultural purposes, in which the drainage from manured fields, irrigated districts or manufacturing establishments finds its way into the supplying s ream, should be condemned, as such contamination of the water renders it wholly unfit for domestic purposes. And Professor Frankland, probably the very highest living authority on hydrology, says that "there is no process practicable on a large scale by which that noxious material (sewage matter) can be removed from water once so contaminated, and therefore I am of opinion that water which has been once contaminated by sewage or manure matter is henceforth unsuitable for domestic uses."

And I see that upon quite a recent examination and analysis he has utterly condemned the water of the upper Thames as source of additional supply to London, upon the ground of its contamination from manured fields and the great number of fungoid germs, both visible and microscopic, which it contained. Much statistical information was given to show the wonderfully improved sanitary condition of London, due to the improved condition of its water supply, especially in times of great epidemics. Our own Health Officer here reported officially a few weeks since that at least 25 per cent. of our recent extraordinary mortality was due to the condition of our sewers, resulting from insufficient flushing, and I think no one can doubt what would have been the fearful mortality had we been visited by Asiatic cholera under such a condition of things, as we were in the fall of 1850. The water which we propose to deliver to the city, and which will be entirely protected from contamination, contains only 1½ grains of solid matter to the gallon, being about one grain of the carbonate of lime and the half grain consisting of the salts of soda and potassa.

The watershed is a granite formation, and the line of the canal will pass over a slate belt, so that it can neither become impregnated with inorganic substances or contaminated by organic ones.

In closing this subject I do not know that I can do better than to quote portions of a recent able report made by Dr. Cresson, at the request of the engineer of the water works of Philadelphia, in consequence of the serious contamination of the waters of the Schuylkill by the sewage from various manufactories which drained into the river. The report contains the result and conclusions of all the more recent investigations in various parts of the world, and is a convenient epitome of the whole subject from a hygienic stand point. He says:

"The following extracts from "The Sewage Question," by Krepp, show the mode of the propagation of epidemics, and from a study of the conditions therein stated we are able to learn the means of prevention and of cure should epidemics unfortunately make their appearance."

"Dr. Klob, of Vienna, has recently, by means of a microscope of 800 to 1,000 power, discovered in the evacuations of cholera patients millions and millions of microscopic fungi, very similar in form to common mushrooms."

"That these fungi form the basis and medium of propagation of that terrible disease there can hardly be any more doubt, as all kinds of fungi must rapidly propagate under favorable circumstances."

"The most eminent physicians in the southern part of the United States now acknowledge that yellow fever is much promoted, if not actually generated, by the decompositions of large masses of human fæces left exposed to the open air, * * * the infection by yellow fever is simply caused by the germs of infusoria or fungi, developed by a combination of fœcal matter with vegetable substances putrifying together under the influences of a torrid clime."

"Both yellow fever and cholera germs, whether of the vegetable or animal, fungus or infusoria class, abound of course in the evacuations of the stomach and bowels of the patients, a single drop of which, however diluted, contains millions of these poisonous atoms, which are ever taken up in the air by the evaporation of the infectious fluid, and afterward returned in the rain."

"The scientific investigations of the celebrated Professor Pettenkofer, of Munich, have thrown additional light upon this subject, and disclosed important facts, which may be summed up as follows:

"The origin of cholera lies in a specific ferment or germ contained in the excrements of cholera stricken persons, or even of otherwise healthy people coming from an infected locality."

"Cholera, if once introduced in the shape of this germ, develops itself into an epidemic only in such localities where the water, circulating in a loose, porous soil, is impregnated with fœcal matter through percolation out of cesspools, sewers and gutters."

"Such polluted subsoil water becomes the more dangerous when, by atmospheric influences, it alternately rises and falls, leaving in the latter case the upper strata impregnated with putrid organic matter to dry up, and thereby exhale volumes of most poisonous gases, which enter the human system through our lungs."

"Cholera is, therefore, propagated not only by the atmosphere, when charged with fœcal gases, but also by wells, when contaminated by excremental percolation; the latter being by far the more dangerous mode, as the cholera ferment or poison is much more concentrated and powerful in the water we drink than in the air we inhale."

"In the year 1849, nearly all the water used in London for drinking and culinary purposes was notoriously contaminated by cess-pools and water closets, in many instances even by direct percolation of the evacuations of cholera patients. Fortunately, the quality of London water has since improved. Hence the mortality by cholera in the years 1849, 1864 and 1866 has decreased as follows:

1849, 62 in 1,000 inhabitants.
1864, 43 " "
1866, 18 " "

"When river water holds in suspense effete organic substances of the animal or vegetable kingdom, a process of combustion rapidly goes on by the oxygen contained in the water itself; and when all the oxygen which for that purpose can be spared is consumed, the remaining organic ingredients pass into a state of putrefaction."

"From the above statements it appears that a condition of alkalinity is necessary for the propagation of typhoid and choleritic disorders, and all the modern authorities assert the danger of drinking alkaline waters containing much sewage."

I am fully aware that in times of health we are not likely to realize or perhaps provide as we should do against the horrors of pestilence, but if what I have said and quoted is not enough to show the great importance to public health of an abundant supply of pure fresh water, nothing which I can add, I am sure, can do so. In undertaking to show that our water contains every requisite and condition of a supply as prescribed by the highest

authorities, I have been compelled to review the facts and arguments which all recent discussions of this subject have elicited, and without which no complete investigation can take place. In doing so I wish to disclaim all intention of applying them to any other scheme you may have under consideration. I do not propose to disparage or reflect upon any one's property, directly or indirectly, and have merely stated these facts as essential to and inseparable from every discussion of the water question.

In a few days I hope to be able to submit to you in writing our terms for the sale and introduction of this water. As yet I have not been able to convene our Board for a discussion of the subject, having only a day or two since obtained the estimates of the cost of construction, based upon the specifications of your engineer. All that I can say at present is, that I find from these estimates that we shall be able to state a figure considerably less than $16,000,000.

Respectfully submitted,

LOUIS A. GARNETT, President.

El Dorado Water and Deep Gravel Mining Co.

BLUE LAKES PROPOSITION.

To the Board of Commissioners for Water Supply for the City and County of San Francisco:

The undersigned propose to furnish to the City and County of San Francisco the water supply known as the "Blue Lakes," being the sources of and tributaries of the Mokelumne River, consisting of the Blue Lakes, three in number; numerous small lakes in the same vicinity; the North Fork of the Mokelumne River; Bear River; Rubicon; Summit City Fork; the Middle Fork of the Mokelumne River; the South Fork of the Mokelumne River; Licking Fork; Bear Creek; Blue Creek, and their watersheds, and within the time, and on the terms and conditions hereinafter stated, to build and construct works therefrom, of the description, capacity, style and manner of construction hereinafter stated, suitable to conduct the waters thereof to the said City and County, in such quantity as may be required for the use of the inhabitants of said City and County, and to sell, convey and deliver to said City and County, the said works, ditches, canals, reservoirs, water pipes and other property to be constructed; together with all our right, title and interest, and of each of us; all the right, title and interest of the Amador Canal and Mining Company; all the right, title and interest of Dora Clark; all the right, title and interest of Hugh Murray; all the right, title and interest of Thos. W. Mitchell, in or to the said water sources, and each of them; and the water rights, franchises and privileges enjoyed by us or either of us; or by them, or either of them, pertaining thereto.

Also, that certain ditch or canal, commencing at a point on the south side of the said North Fork of the Mokelumne River, forty-one rods above the mouth of Blue Creek, aforesaid, in Calaveras County, in said State; and extending westerly along the south side of said North Fork of the Mokelumne River to said Blue Creek, a distance of forty-one rods, more or less; and also that certain other ditch or canal known as "Clark's Ditch," or "Clark's Canal," situated in said Calaveras County, taking the waters of said South Fork at the southern point of Blue Mountain, in said County, and extending in a westerly direction to Railroad Flat, Mosquito Gulch and Rich Gulch Flat, in said County, a distance of thirty miles, more or less.

The works to be constructed by us, and so conveyed and delivered to said City and County as aforesaid, are as follows, to-wit:

First. A canal commencing on the south bank of the Main North Fork of the Mokelumne River, forty-one rods above the mouth of Blue Creek, heretofore mentioned, in said Calaveras County; thence on or near the line of the Scowden Survey, to the Calaveras Butte Valley Reservoir, in sections 33 and 34, Township 5 North, Range 11 East, in said County, a distance of fifty-one and three-fourths miles, more or less, of the following dimensions when finished and ready for use, to-wit: six feet wide on the bottom, seven feet deep, and nine feet six inches wide on the top, with a grade of six feet and four-tenths per mile, having a berm six feet wide on the outer or northerly side of the canal, and two feet wide on the inner or southerly side thereof; except through tunnels and flumes, where the grade will be regulated to suit the circumstances of each particular case, maintaining the full capacity of the canal at other points.

Where the canal is in rock excavation not requiring rock lining or walling, the walls shall be constructed with slopes most convenient for excavation.

Where the character of the ground favors it, the canal will be made wider, and less in depth, than the form first given above—but, in all cases, will maintain a cross-section of forty-five feet below the water line of the canal; which is placed at a distance of one foot below the top thereof.

Where the canal passes through good firm rock excavation, the sides and bottom will be brought to a uniform surface, and grade, and of the dimensions required; where not in good firm rock, the sides and bottom will be paved and lined, with good stone, not less than six inches in thickness, carefully laid by hand, making good and substantial work.

On side-hills, the canal will be constructed, partly in excavation and partly by building a double stone wall from a solid foundation below; and filling in for the outer wall. This plan will only be adopted where substantial and secure work can be made by it; and with the approval of the City and County's Engineer. In all other cases, on side-hill work, the canal will be wholly in excavation; and the banks made substantial and secure.

The line of the canal and the material used for embankment, shall be thoroughly grubbed, cleared, and freed from vegetable matter; and the natural surface, where embankments are built, will be picked, plowed, or cut in steps, to secure a bond between the embankment and the natural ground.

All trees standing near the canal and likely to fall into or upon it will be removed; also all brush or other vegetable growth likely in any manner to injure the canal or foul its water.

In crossing ravines, culverts of rough stone masonry, laid in cement mortar, will be constructed of such size and capacity as may be required to carry off the maximum surface drainage without injuring the canal or mingling with its waters.

Catch drains will be constructed at all points where necessary, and of sufficient capacity to carry off the surface water on side-hills.

At all road or stock crossings, substantial bridges will be constructed.

In places found impracticable for canal construction, flumes of the best sugar pine lumber will be substituted for the canal; the construction of which shall be of the most substantial character and approved style, and of a capacity equal to the full capacity of the canal.

Suitable waste-weirs will be constructed at all necessary and convenient points on the line of the canal, subject to the approval of the City and County's Engineer.

Six tunnels will be excavated on the line of the canal, of the following lengths, to wit: one 1,600 feet; one 200 feet; one 1,000 feet and three of 100 feet each—all of the same carrying capacity when finished, as the maximum capacity of the canal. These tunnels, where the material is not sufficiently firm to stand securely without, will be lined with brick or stone masonry, laid in cement mortar; and of such thickness as shall be designated by the City and County's Engineer.

At points where the canal is exposed to stock or other encroachments, it will be fenced on both sides with a strong permanent post and board fence.

In crossing deep ravines, where necessary, wrought iron pipes will be used; and in such cases the weight and strength of the iron, the size of the pipe, the manner of its construction and the coating of it, and the mode of laying it, will be in accordance with the specifications and directions of the City and County's Engineer.

On comparatively level ground the canal will be made partly by excavation and partly by filling, so arranged as to utilize all the material handled.

Head-works will be constructed in a substantial manner of cut stone masonry, laid in cement mortar, and furnished with iron gates of an approved pattern, at the point of the diversion of water on the North Fork of the Mokelumne River, forty-one rods above the mouth of Blue Creek; on the Middle Fork of the Mokelumne River, where the line of the canal crosses the same, at its junction with Bear Creek; and also on the South Fork of the Mokelumne River, at its junction with the Licking Fork. All this work will be executed in the best style of workmanship, and in a manner calculated to secure the greatest permanency and the most security against accident or disaster.

Second. A reservoir will be constructed at the terminus of the canal, known as the Calaveras Butte Valley Reservoir, requiring 408,600 cubic yards of embankment, with a holding or storage capacity of 564,570,000 gallons The inner slopes of the embankment of this reservoir will be paved with good rock not less than twelve inches thick. An outlet tunnel will be excavated through solid material and not through the embankment, lined with brick or stone masonry, laid in cement mortar, where necessary; and provided with a suitable gate of an approved pattern to control the outflow of water.

All this work will be done in a thorough manner under the direction of the City and County's Engineer.

Third. A reservoir will be constructed at Livermore Valley, at an elevation of five hundred and forty feet above the City base; requiring 436,600 cubic yards of embankment and 384,800 yards of paving; affording a storage capacity of 15,000,000,000 gallons; with a suitable outlet tunnel, removed from the embankment, in solid material lined with brick or stone masonry, laid in cement mortar, where necessary, and provided with suitable gates of an approved pattern, and a wrought iron pipe, of requisite size and strength, to connect with the main-pipe hereafter referred to. All this work will be done in a thorough manner under the direction of the City and County's Engineer.

Fourth. A wrought iron pipe will be constructed and laid down from the Calaveras Butte Valley Reservoir to the New City Hall in the City and County of San Francisco, on a line conforming as nearly as may be to the Scowden Survey, except it shall pass by the most practicable and shortest route from Niles Station around the southern end of the Bay of San Francisco. This iron pipe shall be forty inches in diameter in the clear, from the Calaveras Butte Valley Reservoir to Livermore Pass; and forty-two 13-100 inches in diameter in the clear, from Livermore Pass to the New City Hall in the City and County of San Francisco; shall be constructed of iron of the thickness and strength and in the manner, laid and completed with man-holes, air-valves, gates and blow-offs, subject to the tests, coated with asphaltum paint, covered with earth, cross the San Joaquin River and other streams, in conformity with the specifications of the Engineer of your Board, now in the hands of the undersigned.

It being understood that, at the expense of the City and County of San Francisco and by its authority and direction, its Engineer and other authorized agents shall survey, determine, locate, mark out and deliver to us, the line, route and sites of said canal, head-works, reservoirs and pipes, from the initial point on the North Fork of the Mokelumne River hereinbefore referred to, to the New City Hall in the City and County of San Francisco, all ready and complete for the construction of said canal, head-works, reservoirs and pipes, as soon after the execution of the contract for the construction and sale of these works to the City and County as the same may be required for the construction and completion of the same.

The water sources, rights, privileges, franchises, property, canals, reservoirs, pipes and other works, hereinbefore specified and described, constructed and complete as a water supply for the use of the inhabitants of the City and County of San Francisco, will be conveyed, turned over, and delivered to the authorities of said City and County, on or before the first day of January, 1881, reserving to said Amador Canal and Mining Company, its successors and assigns, the possession, free use of, and control, with the right to use, without any consideration or equivalent to be paid or received therefor, so much of the waters of the said North Fork of the Mokelumne River, at a point on said river where said Company's canal taps said stream, and of all waters flowing naturally to said point of diversion, as said company shall require in the prosecution of its business, until the said waters shall be required for the use of said City and County; and, to said W. V. Clark the use and control of the said Clark's Ditch or Clark's Canal, and water sufficient to fill the same (without charge), until the same shall be required for the use of said City and County, for the sum of fourteen millions dollars, payable in the bonds of said City and County specified in the Act creating your commission, as follows, to-wit: seven hundred thousand dollars on the ratification, by a vote of the people of said City and County at the election provided for in said Act, of the purchase and sale hereinbefore proposed, and the execution of a contract and bond by and on behalf of the undersigned, for the faithful performance and execution of all the terms and conditions hereinbefore stated, and to be stated in said contract; and the execution and delivery by us of a trust deed of all the interests hereinbefore mentioned in and to all the water sources, water rights, privileges, franchises, and property hereinbefore described, now existing (with the reservation to said Amador Canal and Mining Company, and to said W. V. Clark hereinbefore stated), to such person or persons as said Commissioners shall designate, in trust for the said City and County, as additional security on our part for the due performance of the terms of said last mentioned contract, with full power to such trustee or trustees, to convey, absolutely, to said City and County, all of said interests in said above mentioned existing property, whenever said City and County shall demand the same, free from all liens and from all claims, legal or equitable, we, or the parties mentioned herein, or either of us, or either of them, may have therein or thereto; reserving to said Amador Canal and Mining Company, and its successors and assigns, the possession, free use of, and control, with the right to use, without any consideration or equivalent to be paid or received therefor, so much of the waters of the said North Fork of the Mokelumne River, at a point on said river where said Company's canal taps said stream, and of all waters flowing naturally to said point of diversion, as said company shall require in the prosecution of its business; until the said waters shall be required for the use of said City and County; and to said W. V. Clark the use and control of said "Clark's Ditch," or "Clark's Canal," and water sufficient to fill the same (without charge), until the same shall be required for the use of said City and County; and thereafter seventy-five per cent. of the proportionate value or price of completed work, or iron delivered on the line of the proposed pipe, at the end of each thirty days after the commencement of the work of construction, such proportionate value of completed work to be estimated and determined by said City and County's Engineer, on or before the tenth day of each month, of all work completed, and of iron delivered within the last preceding month.

After the canal and head-works shall have been completed from the initial point on the North Fork of the Mokelumne River to the Calaveras Butte Valley Reservoir aforesaid, payment shall then be made on such completed work (including payments previously made thereon) of ninety per cent. of its proportionate value.

When the canal and head-works aforesaid shall have been completed as aforesaid, and the pipe line from the Calaveras Butte Valley Reservoir to Livermore Pass shall have been completed, then ninety per cent. (including previous payments) of the proportionate value of said pipe line shall be paid; and thereafter ninety per cent. of the proportionate value of all completed work or iron delivered on the line of the works shall be paid, on the monthly estimates hereinbefore specified. The remaining ten per cent. shall be paid on the completion, conveyance, delivery and acceptance of the entire works and property.

If the undersigned shall fail to perform the conditions of the terms of the contract to be entered into in pursuance of this proposition (if accepted by your Board and ratified at said election by a vote of the people of the City and County of San Francisco) then, and in that case, the said City and County shall have the right to demand of and receive from the undersigned a conveyance and delivery of possession of all the rights, franchises, privileges, property, ditches, canals, reservoirs, canal and pipe in course of construction, and materials on hand for that purpose, hereinbefore proposed to be conveyed; and the said trustee or trustees hereinbefore mentioned, shall immediately convey by deed absolute to said City and County, all the rights and property he or they shall then hold in trust for said City and County by virtue of the trust deed hereinbefore mentioned, without further compensation than may have been paid prior to such default on our part.

Since the undersigned were furnished with specifications for the canal by your Engineer, it has been determined that a line commencing at the head of the Amador Canal and Mining Company's canal, on the north bank of the said North Fork of the Mokelumne River; thence following the line of the said Amador Canal and Mining Company's Canal westerly, seventeen and one-half miles; thence by iron pipe, natural channel and canal, southerly across the Mokelumne River to station 1774 of the Scowden Survey, hereinbefore referred to; thence following the line of the Scowden Survey to the Calaveras Butte Valley Reservoir, will shorten the canal line by fourteen miles.

Should you determine to adopt the canal line last mentioned, in place of the line upon which the foregoing offer is based, we propose to construct the canal on that line in all respects as hereinbefore described for the construction of the canal on the first line named, varying only as the circumstances of the new line may require; and to reduce the price hereinbefore named, three hundred thousand dollars; or, should a route for canal be found commencing on the south bank of the said North Fork of the Mokelumne River, opposite the head of the said Amador Canal and Mining Company's Canal, which shall not be longer or more expensive in construction than that on the north side of said river, above described, we will construct the canal on that line, and make the reduction above stated.

Should you determine that the Livermore Reservoir is not a necessity to this proposed system of water supply, and may be omitted in the construction, a further reduction of two hundred thousand dollars will be made in the price above named; in addition to which we will construct a reservoir at Livermore Pass, section 20, T. 2 S., R. 3 E., Mount Diablo Meridian, according to the specifications of your Engineer for the construction of a reservoir at that place, now in our hands.

This reservoir will be constructed, in the event named, without additional cost.

It is believed that on a resurvey a shorter pipe line than that established by the Scowden Survey will be found. Should that expectation be realized, and the cost of construction be thereby lessened, we agree to make a corresponding reduction in the price stated in this offer.

All of which is respectfully submitted.

A. HAYWARD,
A. H. ROSE,
W. V. CLARK,
By A. C. ADAMS, his Attorney.

Dated July 23, 1877.

PROPOSAL OF THE MOUNT GREGORY WATER AND MINING COMPANY.

To the Honorable A. J. Bryant, D. J. Murphy and Geo. F. Maynard,
Board of Water Commissioners:

Gentlemen—A few months since I had the honor of presenting for your consideration, the proposition of the Mount Gregory Water and Mining Company, for the sale to the City and County of San Francisco, of the right to the waters of the Rubicon River, or the South Fork of the Middle Fork of the American, claimed by the company, which proposition is now renewed. The scheme herein proposed is one of the grandest and most important, as well as the simplest for the supply of the City of San Francisco, as well as the cities en-route, that can be brought to your notice. No one's rights are infringed by it; no water is taken that is used, appropriated, or required by man or country from its source to its mouth, which cannot be said of any other proposition, excepting the pumping ones; but this appropriation will be a benefit and a blessing to all along its line, from the summit to the sea.

The water of the Peninsula will be needed by the cities, villages, suburban residences, manufactories, farms, dairies, and gardens along its slopes. The water of Clear Lake is required on the plains of Yolo. The diversion of the water of the Mokelumne and the Blue Lakes, would, as a prominent mining man of the region said, be the death blow to placer mining in Calaveras County; and similar damage follows the appropriation of other mountain streams. In this particular, the Rubicon, is a marked exception. The sources of the stream are among the snow-covered peaks, granite hills and precipitous canyons of the Sierra, now uninhabited and without prospect of occupation except by the tourist and the sportsman. In such a condition the stream continues, until it passes the snow line and the point where it is proposed to divert it for the City's use. Such being the character of the country, there is great probability that a concession by Congress may be obtained affirming the franchise, withdrawing the land from sale, and devoting it to the purpose of the watershed, and with its many sparkling lakes and grand scenery, its pleasant fishing and spirited game, consecrating it as a grand mountain park, a great desideratum of our pleasure and health-seeking citizens. This region embraces an area of about 400 square miles, occupying that slope of the high Sierra directly west of Lake Bigler, and containing a large number of small mountain lakes of the most lovely and picturesque description. The Rubicon is a large and rapid mountain torrent, the largest of the Sierra from Kern River to Feather River, flowing in August last a volume of 300,000,000 gallons, daily, near the point whence it is proposed to divert it, always pure, soft and cold, the most perfect for any or every purpose that could be desired for human use. All know the absolute purity of the water from the snowy mountains, and any certificate from a chemist would be like painting the lily or adding a new color to the rainbow, as the analysis by the palate and stomach is far more satisfactory, indisputable and valuable, and can be had without money and without Price.

Perpetual snow is found in many localities, and frosts prevail nearly every night of the year, thus keeping the water cold and pure. This freshness, if retained by being brought in well-protected pipes or covered canal, or without exposure in storage reservoirs, would be of unspeakable advantage and comfort, particularly to the great masses of our people who cannot at all times have filters and ice at their convenience. Its softness, too, would add to the pleasure of the bath, and greatly to the economy of the laundry, while it would also enter into many manufactures now forbidden, without it.

But it is unnecessary to explain to thinking minds the great necessity of an abundance of pure water in large cities, nor to show how it adds to the luxuries, the comfort and health, as well as to the general economy of life and business: nor to expatiate upon the

future greatness of San Francisco. Suffice it to say, here, with the region about the Bay, will be one of the most populous, refined, wealthy and luxurious cities of the earth, and the calculations for the future should take this view in considering questions pertaining to it. A broad and comprehensive view will include the surrounding region when the City, one in reality and interest—if not in municipal incorporation—shall occupy both shores of this capacious harbor; and in that idea is our plan elaborated.

PROPOSITION.

The Mount Gregory Water and Mining Company propose only the sale of their water right, understanding such acquisition to be the object of this commission, and this inquiry the elucidation of the plan. The sum asked for the water right is $250,000, in payments as authorized by statute. The said right was acquired by locations made in October, 1871, and April, 1872, under and in conformity with the laws of the United States, the State of California, and in accordance with the customs of the country. These locations were duly recorded in the Recorder's Office of El Dorado County, being the first on record of any claim to the waters of the main Rubicon; and this title the Mount Gregory Water ahd Mining Company will defend against any claimant but the United States Government. The company earnestly beg a kind consideration of their plan, irrespective of title, and a thorough investigation of title afterwards, which they firmly believe is perfect and invulnerable.

This scheme of supply contemplates taking the water from the river near where it crosses the 12th Township, meridian, east of Mount Diablo, where the elevation of the stream is about 2,500 feet above the level of the sea, falling at the rate of about 100 feet per mile, the water being pure and uncontaminated by mining or any cause. From this point the company formerly proposed to lead the water by a continuous iron pipe to San Francisco, a distance of 150 or 155 miles. The route would be down the south side of the cañon of the Middle and North Forks of the American, to any convenient place of crossing the North Fork; thence in a straight line to the Sacramento River, near Sacramento City; thence following the California Pacific Railroad to the most feasible point for crossing the Straits of Carquinez; thence following the railroad by Oakland to such point as shall be selected to cross the Bay to San Francisco. This plan has contemplated the crossing of the Straits of Carquinez and the Bay by submerged pipe. They would propose a canal, flowing into a 60-inch pipe for a short distance from the head, until a pressure of 300 feet would be obtained; the same from the first reservoir in El Dorado County, the remaining pipe being 44 inches in diameter. Such pipe, under such pressure, would carry 50,000,000 gallons. Three reservoirs are proposed—one in El Dorado County, at an elevation of 1,200 or 1,500 feet above the sea; one near Vallejo, if practicable, and one in the Contra Costa Hills. The pipe would be provided with waste gates, air valves, air escapes, etc., at all proper places.

COST.

The cost may be estimated as follows: Taking such iron as was used in the greatest depression of the aqueduct supplying Virginia City, which bears a pressure of 1,750 feet, and is of No. 0 iron weighing 13 pounds per square foot, the present price being at the rate of 5 cents per pound; a pipe 44 inches in diameter contains 46 square feet in each 4 feet of length; longitudinal straps over seams, and bands over joints, 4 inches wide of same iron, make 52.27 feet to each length of 4 feet; cost of each mile of pipe, $44,892 for iron, $1,320 for rivets, $3,000 for trench, $10,500 for making, $1,320 for coating with asphaltum, or a total of $61,042 per mile, or $9,156,300 for pipe. To this is added $20,000 head-works, $500,000 for three reservoirs, $3,000 for crossing the American, $7,000 crossing the Sacramento, $100,000 crossing Straits of Carquinez, $500,000 crossing the Bay of San Francisco, $100,000 freight, $150,000 gates, air-valves, air-escapes, etc., $250,000 water right, $564,305 (five per cent.) for engineering, contingencies, etc , making a total of $11,972,940, and this can be reduced one million dollars by constructing a canal from the point of diversion of the

water to the first reservoir in El Dorado County, which would place the total cost at $10,972,940 or $11,000,000 in round numbers. This does not include the street pipes nor reservoirs in the City, but the City having many favorable locations in its various parks for reservoirs, we may estimate that $2,000,000 will provide the complete system. Neither is an estimate made for tunneling the Bay, as there is no sufficient knowledge of the formation of the bed on which to find a basis. It will be simply a question of water. If indurated mud, or rock without a large flow of water through it, the work would be comparatively light, and $500,000 per mile would probably cover the cost, tunneling, arching, etc. Not taking the tunnel into consideration, this work would be accomplished in two and a half years, or probably less. There is no difficult work in any part of the route, no dangers from land or snow slides as the line of works is below the snow, no deep cañons nor mountain ranges to cross, and all parts are of easy access. From the crossing of the North Fork of the American River, near Folsom, the route proposed is a direct line to Vallejo over a generally level plain, following from the crossing of the Sacramento the line of the California Pacific Railroad. No more favorable route could be found.

CONCLUSION.

The predominating advantages of this proposition are the following:

1st. It is the largest body of water nearer than Lake Tahoe.

2d. The stream will furnish a sufficient supply for this City at the driest season without any reservoir, and can be increased indefinitely by a system of reservoirs very cheaply constructed, there being some thirty small lakes in the region of the source.

3d. The title that can be conveyed is perfect and undisputed.

4th. A large extent of fertile soil near the line of pipes, now unproductive, can be irrigated and made very productive.

5th. Sacramento, numerous stations on the California Pacific Railroad, Fairfield, Benicia, Vallejo, Mare Island Navy Yard, Oakland, Alameda and other places are directly on the route or at small distances from the direct air line from where the pipe would leave the foot hills of the Sierra, and are to be supplied.

6th. A drought, such as occasionally occurs in the Coast range and valleys of California is never known in the high snowy mountains that form the sources of the Rubicon.

7th. The route is feasible, direct and short. These statements cannot be controverted.

JOHN DAGGETT, President.
MYRON ANGEL, Secretary.
Mount Gregory Water and Mining Co.,
Office, 24 Merchants' Exchange,
San Francisco.

THE SAN JOAQUIN AND SAN FRANCISCO WATER WORKS COMPANY.

PROPOSITION No. 1.

To the Honorable the Board of Water Commissioners for the City and County of San Francisco:

The San Joaquin and San Francisco Water Works Company, a corporation duly organized, incorporated, and now existing under and by virtue of the laws of the State of California, begs leave to submit to your Hon. Board the following proposition relative to the construction and sale to the City and County of San Francisco of water works, having an available capacity for the delivery of fifty-five millions of gallons daily, and forming the basis

and very considerable portion of finished work of a system in which this delivery may be made one hundred millions of gallons daily at a minimum additional cost. The proposition embraces structures whereby the great volume of the San Joaquin River, after it shall have been fed by the waters of the Stanislaus, the Tuolumne, the Merced and the Upper San Joaquin, may be tapped and brought in such quantity as required, directly to the point of greatest demand and use, namely: the most densely inhabited portion of the City of San Francisco. This water is derived directly, and except during the immediate prevalence of the rainy season, solely from the snow fields of one of the most elevated portions of the high Sierras. Upon the merging of the above named rivers into and with the channel and body of the main San Joaquin, it is carried on to the junction with the Sacramento and the waters of Suisun Bay. Before reaching the salt waters of said points of junction, by some sixty miles, the river spreads into an extensive basin with three main channels or arms, which rejoining at a point at least twenty miles above where the water begins to be brackish, combines such length, breadth and depth as to provide not only great capacity as a settling reservoir if needful, but also a top tidal prism of between 3,000 and 4,000 millions of gallons of unexceptionally good, pure, potable water, available for use and constantly fed by the inflowing river. The statement of the sources precludes the necessity for discussion as to the quality of the proposed supply. Pursuing, however, the course adopted with all of the others of this group of mountain waters proposed as a city water supply, the accompanying report and analysis (see page 88) of Prof. Price of samples of the water taken by himself at the place of appropriation on the west side of the basin herein mentioned, is submitted.

This analysis, with comparisons made and shown with the waters of other cities, as also with the waters of Spring Valley and Clear Lake, contains its own argument.

Under the authority of the laws of the State of California and of the United States, the company has taken all needful steps in securing control of water rights and the right of diversion of this San Joaquin water, at what is the most suitable locality at which this portion of the river can be tapped by the works of appropriation.

For this appropriation and final use the company now propose to provide a double set of pumping works, connected by proper conduits, in which there shall be: First, a Low Service receiving and pumping station in the vicinity of Marsh's Landing, in Contra Costa County, connected with the point of appropriation on the one side by a closed conduit of one hundred millions of gallons daily capacity, and on the other side with the City of San Francisco by an iron conduit about fifty-seven miles long, through which the water to be consumed shall be, by proper machinery, forced directly into the City of San Francisco, and delivered there into a low level receiving reservoir; and Second, a San Francisco Service of pumping works, which shall take the water thus received, and lifting it to such levels as shall meet the wants of the city, produce thereby such heads over all portions of the city's very irregular surface as shall secure as near as may be uniform an inexpensive distribution.

The specific structures of this system of works, which the company will construct for the consideration to be named hereafter, may be briefly enumerated as follows:

FIRST. OF THE LOW SERVICE PERMANENT WORKS.

(*a.*) HEAD-WORKS at the place of appropriation of water, designed and constructed to pass and to control a volume of one hundred millions of gallons of water daily, into the conduit connected therewith; a conduit of ten and one-half feet internal diameter, so constructed that no water, except through the head-works, shall flow into or through it, and of a daily capacity of one hundred millions of gallons, and of a length of twelve miles, more or less, connecting said head-works with a pair of Receiving Wells, located in vicinity of Marsh's Landing, and built in the best manner, of hard brick laid in hydraulic cement, and comprising all needful connections, gates, coverings and appliances requisite to make

them effective in sustaining a constant water supply to the pumps, to the ultimate daily extent of one hundred millions of gallons.

(*b.*) In the vicinity of Marsh's Landing sufficient grounds acquired and fenced to meet all demands for buildings and structures which, under the plan here proposed, will be requisite for an ultimate supply of one hundred millions of gallons daily; Engine and Boiler Houses of brick, designed to accommodate sufficient of the "Worthington Duplex" pumping machinery to produce a flow, when required, of fifty-five millions of gallons, daily, into the City of San Francisco; pumping machinery, and boilers and appliances, all in place ready for action, and of capacity sufficient for the demand, at time of completion of works, of, say twenty millions of gallons, daily.

Pump Wells connected by first-class brick channels or culverts, with the receiving wells, noted hereinbefore.

Ships Wharf, connected by iron track, with coal sheds and coal yard in immediate proximity to boiler rooms; wooden tenement buildings of capacity and design suitable for engineers, firemen and helpers, required to operate the machinery adopted in this plan of works, up to a delivery of fifty-five millions of gallons daily.

(*c.*) From this low service pumping station an iron conduit fifty-seven miles in length, more or less, of six and one-half feet internal diameter, constructed in such manner and of such metal, as to carry fifty-five millions of gallons of water, daily, without being strained under its maximum work beyond 12,500 pounds per square inch of metal section; together with all stop gates, air-valves, sediment chambers and cocks, and other necessary appliances, to its effective working from end to end. Also, with a right of way sufficient to accommodate another conduit when required, and fenced through all private lands, or wherever it may be proper to provide such protection of the grounds.

The line of this conduit to be from the low service pump station; thence back of Antioch, New York and Pittsburg, to the low lands bordering Suisun Bay, and thence to and in front of the town of Martinez, around the bluff line of Carquinez Straits and San Pablo Bay, usually inside of the railroad line, and through tunnels or galleries to be provided, to San Pablo; thence through Oakland, to the mouth of and through the tunnel under the Bay of San Francisco to the receiving station within that City.

(*d.*) A wrought iron Tunnel Tube, of about five miles in length, of ten and one-half feet internal diameter, and laid beneath the bottom of the Bay of San Francisco, from shore to shore, and at such depth, that the top of the tube shall nowhere have less than ten feet of material over it. This tunnel, with its contained water pipe, will safely provide a passage across the Bay for one hundred millions of gallons of water, daily, when required, and delivered to the Oakland end of the tunnel conduit. All appliances that belong to said tunnel and water pipe within, including an endless wire rope, properly hung on pulleys, and with which, by means of engines and drums on the San Francisco side, communication through the tunnel, from end to end, is established and maintained, and with which, also, by means of an iron railway laid on top of the water pipe, and trucks or cars to run thereon, gangs of workmen may be passed to and fro, in necessary works of inspection and maintenance; together with the brick tunnel ends or shafts upon the main shores, and through which communication is effected from the ground surface with the tunnel interior.

SECOND. OF THE SAN FRANCISCO STATION AND WORKS.

(*a.*) Receiving Reservoir, built in the best requisite manner, of concrete bottom, and sides of pressed brick, laid in hydraulic cement. Within this receiving reservoir the height of the inlet delivery to be about eight feet above mean low tide.

(*b.*) Engine and boiler houses and appliances, fire-proof, of hard brick, and of such dimensions and design as shall best accommodate "Worthington Duplex" pumping machinery to the extent required for a distribution of fifty-five millions of gallons of water daily; together with sufficient "Worthington Duplex" pumping machinery, with boilers

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and all connections ready for use, for the delivery of twenty millions of gallons of water daily, being the amount presumed to safely cover the city's demand at the time of the completion of these works; also with pump wells, and culverts and channels connecting same with the aforementioned receiving reservoir.

(*c.*) The entire series of buildings and reservoir to be surrounded by a brick wall of proper height, containing necessary iron gates.

(*d.*) From the coal and boiler houses a wire rope railway to connect with the wharf where coal is to be landed, together with sufficient cars to meet the immediate demand in handling fuel from ship's side to the boilers.

This wharf to be provided by the city, and during the period of construction of said works to be devoted to the use of the company in the furtherance of said construction.

(*e.*) A telegraph line from San Francisco station through the tunnel to Oakland, and thence to low service pump station, and thence to head works on the San Joaquin River, together with all necessary instruments and batteries for the immediate operation of said line.

No attempt is made in this document to set forth the details of the works thus enumerated; but for the more perfect elucidation of our proposition and method and manner of its execution, we refer you to the accompanying papers, marked A and B, prepared by Col. Wm. B. Hyde, Civil Engineer, which also embrace a vast amount of information upon "water supply."

This company will construct the works therein described as hereinbefore enumerated, and will turn them over to the city, together with water rights, lands and construction plant necessary for estimated future extensions, for the sum of $11,500,000 of the bonds of the City and County of San Francisco.

As prescribed in the law under which these proceedings for the acquisition of water works are conducted said bonds shall be of denomination of $1,000 each, and payable in 30 years from date of issue, with coupons for interest at the rate of six per cent. per annum, payable semi-annually, both principal and interest payable in U. S. gold coin at the office of the Treasurer of said City and County, subject to the restrictions, limitations and conditions which are imposed by said law, the mode, manner and rate of payment of said bonds to be based upon the following terms:

After the agreement upon and adoption of the specifications to govern the construction of the works as herein proposed, and confirmation by the election of the qualified voters of the City and County of San Francisco as provided by law, the engineer of the Board of Commissioners, together with this company's engineer, shall mutually agree upon the number and limiting features of certain subdivisions into which the work as proposed to be built by this company shall be divided. Together with such others as said engineers shall agree upon, these subdivisions shall include as such:

1. The head works, conduit, and all appliances therewith.

2. The works, buildings, machinery, receiving wells, and all connections and appliances of the Low Service pumping station.

3. The main iron conduit and appliances from Low Service pump station to the Oakland end of tunnel, under the Bay.

4. The tunnel under the Bay from and between and including its terminal brick shafts and ground connections, together with its interior structures as specified.

5. The entire series of constructions belonging to the San Francisco station.

6. Right ot way and all necessary real estate for the works.

Then the said engineers shall decide upon and adopt the proportion in value which each of said subdivisions decided upon shall bear to the total amount to be paid this company by the City and County aforesaid for all of the works hereinbefore enumerated. Such

subdivisions, with their relative value as thus ascertained, to form the basis upon which progressive payments shall be made.

As the work advances, and from month to month, the city's engineer, together with the company's engineer as aforesaid, shall agree and decide what proportion the amount of labor and material furnished by the company in such progress bears to the value found and fixed for such subdivision, or any or all of them in which work has been done and progress made and material furnished; and thereupon the engineer for the city shall issue to the company a certificate or certificates, if the work done and material furnished and to be paid for has been advanced in more than one subdivision simultaneously, bearing date the first of the month following that in which work was done and material furnished, and for which the certificate is issued, said certificates stating the facts found as aforesaid. Upon the presentation of the said certificate or certificates by the company or its assigns to the Auditor of the City and County, said Auditor shall audit the same. Thereupon the Mayor of the City and County, subject in all respects to the restrictions, limitations and conditions of the law, shall deliver to the holder of said certificate or certificates, the city bonds, by said law to be provided for such purpose, to the extent of eighty per cent., as near as may be done with $1,000 bonds, of the amount certified to. Upon the completion of the entire works, and upon certificate of the city's engineer thereto, and upon the execution and delivery to the city of such deeds of conveyance as shall be needful as complete evidence of the city's acquired ownership of said works, then in like manner the Mayor shall deliver to said Company or assigns the full number of the bonds withheld and necessary to complete the price and total amount agreed upon between said city and Company.

Immediately upon the delivery of bonds by the Mayor upon certificates as hereinbefore provided, to the extent of said eighty per cent., the said City and County shall have for the amounts of said bonds thus delivered a first lien upon the property which is in process of construction, as a security for the fulfillment of the contract by the Company, but not to interfere in any manner with the use of the same by the Company during their work of fulfillment of the contract with the city.

The Company will complete said works as agreed upon and deliver the water from the head works on the San Joaquin River into the receiving basin in San Francisco, within thirty months from and after the date of the official declaration that the vote of the people has indorsed and authorized the contract; *provided*, the said City and County shall have performed the matters and things in the contract on its part to have been done and performed.

The attention of your Honorable Board is asked to the fact that all of the permanent works hereinbefore proposed, with the exception of portions of machinery necessary to complete this supply, are to have an immediate capacity for the delivery of 55,000,000 of gallons daily; such additions of machinery being the sole subsequent expense to produce that delivery; and further, that the works will require hereafter but the addition of a single line of conduit from the low service pump station to the Oakland end of the tunnel, together with requisite machinery, to be capable of a delivery of 100,000,000 of gallons of water daily into San Francisco.

This proposition includes no estimate or proffer for works and mains of distribution within the city. It will be evident to your Honorable Board that this department of water works, being common to all propositions, is not of necessity a factor in arriving at the relative cost of various projects; and again, unless the city adopt and announce some standard to govern the plan and construction of such works, it will be difficult to secure perfectly just comparative results in the final annual cost of different schemes of water supply, it being obvious that the cost of distribution works, if based upon the character and capacity of the pipage and connections now laid within the city, will be much less than if the corresponding works of Boston, Chicago or St. Louis should be taken as models.

When the city adopts its standard and plans, this company will, if permitted, make a bid thereon, or, at the request of your Honorable Board, this company will prepare and submit plans and estimates for such works as would be specially adaptable to the system of

water supply herein proposed. In the meantime, and to secure a knowledge of the probable cost of this branch of works, the attention of your Honorable Board may be directed to the estimates made by the city's former engineer, Mr. T. R. Scowden, in which, for the distribution works of the proposed "Calaveras" supply, the estimate submitted was $2,617,-239. (Vide p. 38, appendix Municipal Reps.)

The Act authorizing your Commission, and under which you are acting, requires your examination of the water supply that you may adopt; we therefore invite your Honorable Body to an examination of the water supply which we propose to furnish, and shall take pleasure in providing the means of conveyance, on being advised of your wishes in relation thereto. Our proposition will be changed or modified to meet your views, if not involving the essential features of it.

San Francisco, Feb. 21, 1877.

For the San Joaquin and San Francisco Water Works Company.

(Signed) H. D. BACON, President.

THE SAN JOAQUIN AND SAN FRANCISCO WATER WORKS COMPANY.

PROPOSITION No. 2.

To the Honorable the Board of Water Commissioners

for the City and County of San Francisco:

The San Joaquin and San Francisco Water Works Company, a corporation duly organized, incorporated, and now existing under and by virtue of the laws of the State of California, begs leave to submit to your Honorable Board the following supplemental proposition, relative to the construction and sale to the City and County of San Francisco of water works having an available capacity for the delivery of 40,000,000 of gallons daily, and forming the basis and very considerable portion of finished work of a system in which this delivery may be made 80,000,000 or 120,000,000 of gallons daily, at a minimum additional cost.

This proposition, in common with the first proposition of this Company, embraces structures whereby the great volume of the San Joaquin River may be tapped and brought in such quantity as required to the City and County of San Francisco. Referring to said first proposition for such descriptive memoranda, relating to said water supply, as may be important, including a careful analysis of the waters by Prof. Thos. Price, this company now states that, under the authority of the laws of the State of California and of the United States, the company has taken all needful steps in securing control of water rights, and the right of diversion of this San Joaquin water, at what is the most suitable locality at which the river can be tapped by the works of appropriation.

For this appropriation and final use the company now propose to provide a double set of pumping works, connected by proper conduits, and in which there shall be: *First*—A low service receiving and pumping station in the vicinity of Marsh's Landing, in Contra Costa County, connected with the point of appropriation on the one side by a closed conduit of 100,000,000 gallons daily capacity, and on the other side with the City of San Francisco by an iron conduit one hundred and twenty-two miles long, more or less, through which the water to be consumed shall be, by proper pumping machinery, forced or pushed directly into the receiving reservoir at the San Francisco end of such conduit; and, *Second*—A San Francisco service of pumping works, which shall take the water thus received, and lifting it to such levels as shall meet the wants of the city, produce thereby such heads over all

portions of the city's very irregular surface as shall secure, as near as may be, uniform and inexpensive distribution.

The specific structures of this system of works, which the company will construct for the consideration to be named hereafter, may be briefly enumerated as follows:

FIRST. OF THE LOW SERVICE PERMANENT WORKS.

(*a.*) Head works at the place of appropriation of water, designed and constructed to pass and control a volume of 100,000,000 of gallons of water daily into the conduit connected therewith. A conduit of ten and a half feet internal diameter, so constructed that no water, except through the head works, shall flow into or through it, and of a daily capacity of 100,000,000 of gallons, and of a length of twelve miles, more or less, and connecting said head works with a pair of receiving wells located in the vicinity of Marsh's Landing, and built in the best manner, of hard brick laid in hydraulic cement, and comprising all needful connections, gates, coverings and appliances requisite to make them effective in sustaining a constant water supply to the pumps, to the ultimate daily extent of 100,000,000 of gallons.

(*b.*) In the vicinity of Marsh's Landing sufficient grounds acquired and fenced to meet all demands for buildings and structures which, under the plan here proposed, will be requisite for an ultimate supply of 100,000,000 gallons daily. Engine and boiler houses, of brick, designed to accommodate sufficient of the "Worthington Duplex" pumping machinery to produce a flow when required of 40,000,000 of gallons daily into the City of San Francisco. Pumping machinery, boilers and appliances, all in place, ready for action, and of capacity sufficient for a supply of 20,000,000 of gallons daily. Pump wells, connected by first class brick channels or culverts, with the receiving wells noted hereinbefore. Ship's wharf, connected by iron track with coal sheds and coal yard, in immediate proximity to boiler rooms. Wooden tenement buildings, of capacity and design suitable for engineers, firemen and helpers, required to operate the machinery adopted in this plan of works up to a delivery of 40,000,000 gallons daily.

(*c.*) From this low service pumping station an iron conduit one hundred and twenty-two miles in length, more or less, of six and one-half feet internal diameter, constructed in such manner and of such metal as to carry 40,000,000 of gallons of water daily, without being strained under its maximum work beyond 12,500 lbs. per square inch of metal section. Together with all stop-gates, air valves, sediment chambers and blow-off cocks or gates, and other necessary appliances to its effective working from end to end. Also, with a right of way sufficient to accommodate another conduit when required, and fenced at all points where it may be proper and necessary to provide such protection.

The line of this conduit to be from the low service pump station; thence back of Antioch, New York and Pittsburgh to the borders of Suisun Bay; thence to and in front of the town of Martinez, around the bluff line of Carquinez Straits and San Pablo Bay, usually inside of the railroad line, and through tunnels or galleries, to be provided, to San Pablo Valley; thence through Oakland and Alameda, or around back of those cities, following the line of hard ground along the swamp land bordering the Bay to Alviso; thence along the shore-line of the opposite side of the Bay, past the towns of Ravenswood, Menlo Park and others, to a point on the south side of Sierra Point and into the receiving reservoir, there to be located. For the six miles requisite to carry the line through or past the cities of Oakland or Alameda, the line to be laid from the first with two pipes of iron heavy enough to make a safe structure beneath whatever streets or roadways it may be necessary to pass; and providing, so far as the passage of said cities is concerned, water-way for a flowage of 80,000,000 gallons daily, without any additional expense to the City and County of San Francisco.

SECOND. OF THE SAN FRANCISCO STATION AND WORKS.

(*a*) Receiving Reservoir of sufficient size to maintain a steady supply to the San Francisco main pumps, and built in the most substantial manner. Within this receiving reservoir the height of the inlet delivery to be about 28 feet above mean low tide.

(*b*) Engine and Boiler houses and appliances, fire-proof, of hard brick, and of such dimensions and design as shall best accommodate "Worthington Duplex" pumping machinery, to the extent required for a distribution of 40,000,000 of gallons of water, daily; together with sufficient "Worthington Duplex" pumping machinery, with boilers, and all connections ready for use, for the delivery of 20,000,000 of gallons of water daily, being the amount presumed to safely cover the city demand at the time of the completion of these works; also, with Pump Wells, conduits and channels, connecting the same with the afore-mentioned receiving reservoir.

(*c*) Coal Wharf, extending to such depth of water that barges can unload with facility at all stages of the tide; and from the coal and boiler-rooms a railway, to be operated by traveling wire rope, or other economical mechanical appliance, to extend out upon said wharf for the purpose of handling fuel from ship to furnace, with minimum cost to the city.

(*d*) Telegraph Line from San Francisco station as directly as possible to the low-service pump station, and thence to the head-works on the San Joaquin River, together with all necessary instruments and batteries for the immediate operation of said line.

Such details as it is possible to determine at this stage of negotiations, where not discussed and shown in the papers already submitted with Proposition No. 1, will be found in the memoranda accompanying this proposition.

This Company will construct the works as herein enumerated, and as more fully set forth in papers and memoranda herein mentioned, and will turn them over to the city, together with water-rights, lands and construction plant necessary for future extensions, for the sum of $13,000,000, in the bonds of the City and County of San Francisco. As prescribed in the law under which these proceedings for the acquisition of water-works are conducted, said bonds shall be of denominations of $1,000 each, and payable in thirty years from date of issue, with coupons for interest at the rate of six per cent. per annum, payable semi-annually, both principal and interest payable in U. S. gold coin, at the office of the Treasurer of said City and County.

Subject to the restrictions, limitations and conditions which are imposed by said law, the mode, manner and rate of payment of said bonds to be based upon the following terms: After the agreement upon and adoption of the specifications to govern the construction of the works, as herein proposed, and confirmation by the election of the qualified voters of the City and County of San Francisco, as provided by law, the engineer of the Board of Commissioners, together with this Company's engineer, shall mutually agree upon the number and limiting features of certain sub-divisions into which the works, as proposed to be built by this Company, shall be divided.

Together with such others as said engineers shall agree upon, these sub-divisions shall include as such:

1st. The head-works, conduit and all appliances therewith.

2d. The works, buildings, machinery, receiving wells and all connections and appliances of the low-service pumping station.

3d. The main iron conduit and appliances from the low-service pump station at Marsh's Landing or vicinity, to San Pablo valley.

4th. Ditto from San Pablo valley through Oakland and Alameda to Alviso.

5th. Ditto from Alviso to the receiving reservoir.

6th. The entire series of constructions belonging to the main San Francisco stations.

7th. Right of way, and all necessary real estate for the entire works as proposed.

Then the said engineers shall decide upon and adopt the proportion in value which each of said sub-divisions decided upon shall bear to the total amount to be paid this Company by the City and County aforesaid, for all of the works hereinbefore enumerated. Such sub-division, with their relative value as thus ascertained, to form the basis upon which progressive payments shall be made. As the work advances, and from month to month,

the City's engineer, together with the Company's engineer, as aforesaid, shall agree and decide what proportion the amount of labor and material furnished by the Company in such progress bears to the value found and fixed for such sub-division or any or all of them in which work has been done, progress made and material furnished; and thereupon the engineer for the City shall issue to the Company a certificate, or certificates, if the work done and material furnished and to be paid for has been advanced in more than one sub-division simultaneously, bearing date the first of the month following that in which the work was done and material furnished, and for which the certificate is issued, said certificate or certificates stating the facts found as aforesaid. Upon the presentation of the said certificate or certificates by the Company or its assigns to the Auditor of the City and County, said Auditor shall audit the same. Thereupon the Mayor of the City and County, subject in all respects to the restrictions, limitations and conditions of the law, shall deliver to the holder of said certificates or certificate, the city bonds by said law to be provided for such purpose to the extent of 80 per cent., as near as may be done with $1,000 bonds, of the amount certified to. Upon the completion of the entire works and upon certificate of the city's engineer thereto, and upon the execution and delivery to the city of such deeds of conveyance as shall be needful as complete evidence of the city's acquired ownership of said works, then in like manner the Mayor shall deliver to said company or assigns the full number of the said bonds withheld and necessary to complete the price and total amount agreed upon between said City and County and this company.

Immediately upon the delivery of bonds by the Mayor upon certificates as hereinbefore provided to the extent of said 80 per cent., the said City and County shall have for the amounts of said bonds thus delivered a first lien upon the property which is in process of construction, as a security for the fulfillment of the contract by the said Company, but not to interfere in any manner with the use of the same by the company during their work of fulfillment of the contract with the city.

The Company will complete said works as agreed upon and deliver the water from the head works on the San Joaquin River into the receiving basin at the San Francisco works, within three and a half years from and after the date of the official declaration that the vote of the people has endorsed and authorized the contract, provided the said City and County shall have performed the matters and things in the contract on its part to have been done and performed.

The attention of your Honorable Board is asked to the fact that all of the permanent works herein proposed, with the exception of portions of machinery, are to have an immediate capacity for the delivery or carriage of 40,000,000 of gallons daily, additions of machinery being the sole subsequent expense to produce that delivery; and further, that the works will require hereafter but the addition of a single line of pipe from the low service pump station to the San Francisco station, minus the six miles of said double line already laid through Oakland and Alameda, together with the requisite machinery, to be capable of a delivery of 80,000,000 of gallons of water daily into San Francisco.

For reasons stated in proposition No. 1, this proposition also includes no estimate or proffer for works, mains and reservoirs of distribution, although as before based upon the estimate heretofore made upon that subject by the city's former engineer, Mr. T. R. Scowden, an approximate estimate for distribution has been shown and carried forward in the papers accompanying these two propositions, in order to arrive at the final showing of the cost per 1,000 gallons with fully completed works.

Should the Board deem it expedient and necessary that said works shall be completed within three years from date of affirmative vote, this company, for $ more than the price of $ heretofore given, will contract to so complete said works within said three years.

San Francisco, May 2, 1877.

For the San Joaquin and San Francisco Water Works Company.

(Signed) H. D. BACON, President.

PROPOSAL OF SAN FRANCISCO AND SAN JOAQUIN WATER WORKS COMPANY.

OFFICE OF THE SAN FRANCISCO AND SAN JOAQUIN WATER COMPANY,
San Francisco, July 7, 1877.

The Honorable the Water Commissioners:

GENTLEMEN—The company above named, which in these presents I have the honor to represent, submitted to you on a recent occasion a proposition, through Mr. W. S. Watson, to build a system of water works for supplying the city with water from the San Joaquin River. Myself and associates now beg to notify you that we withdraw that proposition and submit the following:

We offer to build all the necessary works and supply the machinery to pump from the river above mentioned 25 millions gallons water per diem and deliver the same into a reservoir situated in San Francisco at any elevation that you may require, from 50 feet upwards to 450 feet above the datum recognized as base in San Francisco.

We offer to build these works and give them up to the city in complete working order within two years after signing the terms of our agreement, for and in consideration of the sum of $10,866,000 of City Bonds, bearing interest at 6 per cent. per annum, and having 30 years to run. Payments to be made monthly, at the rate of 75 per cent. of the value of the work as it progresses, and on the completion and acceptance of the whole work, the balance of the contract price to be paid.

We have the honor to submit to you the following description of the works we intend to carry out:

HEADWORKS.

The headworks shall be located on the San Joaquin River in the vicinity of Mohr's Landing, where there is no vegetable growth nor any other matter to interfere with the purity of the water. The position of this place is far above where the tules grow. The current is marked for miles above, so that there can be no question as to the purity of the water, for when in motion it purifies itself.

Specimens of the water of the San Joaquin River, taken from a locality far below this place, have been already presented to you by Mr. Bacon, together with the results of an analysis, which proves it to be of the best quality for domestic purposes. Further evidences in corroboration of this fact can be furnished, if required.

These headworks shall consist of an "inlet tower" and a "conduit" and "pump wells," of sufficient capacity to furnish 100 million gallons per diem to the pumping machinery. There shall also be a "settling tank," divided into two compartments, each capable of containing 50 million gallons. This is provided with a view of allowing the water time to deposit any sediment it may contain before reaching the pumps.

The water proposed to be furnished is live running water. It will be made to pass through a filter bed situated at the tanks and reservoirs. The water is allowed to settle twice before reaching the city.

The pumping machinery shall consist of two "Worthington Duplex" or "Cornish" pumps, and engines capable of lifting 12½ million gallons each per day; either of these engines to be supplied according to the desire of your Engineer.

The water will be lifted to an elevation of 735 feet above the San Joaquin River, through a conduit of 54 inches diameter and nine miles in length.

It will be of variable thicknesses, according to the height, averaging 42-100 inches. This thickness has been computed so as to render the pipe capable of resisting four times the strain to which it will be subjected.

There are no gates on this line of conduit, and as there will be no shocks caused by the closing of gates, this thickness places the strength beyond question, and insures the stability of the pipe as long as iron can last.

SETTLING RESERVOIR.

At an elevation of 700 feet above the datum recognized as base in San Francisco, the water shall be delivered into a reservoir capable of containing 1,000 million gallons. This reservoir will be formed by building an embankment or "dam" 70 feet high across a cañon suitably situated at the required elevation. The dam will be 30 feet wide on top and slope at the rate of four feet horizontal to one foot vertical; these proportions insure stability and may be considered an answer to all questions on such a subject.

If it should seem more desirable to you, we offer to deliver the water into this reservoir by two lifts—the first lift to terminate at an intermediate reservoir conveniently situated at an elevation of about 400 feet; the second lift will be over the summit into the "Settling Reservoir."

SECOND CONDUIT.

From the Settling Reservoir a conduit of 53 inches diameter will be laid to the city by way of Livermore, Pleasanton, Suñol, Niles, Alviso, Mayfield and San Bruno, and will deliver the water into a reservoir at any elevation you require up to 450 feet above city base. This pipe, as in the former case, will be of variable thicknesses, averaging 3-10 of one inch. Its strength is computed at four times the strain to which its position will render it liable to be subjected, and, as in the former case, it will not be subjected to the water "ram" arising from the closing of a gate; this thickness insures its safety as long as iron can last in any position.

The reservoir in the city shall have a capacity of 251,438,000 gallons and shall be furnished with such water gates and other appurtenances as your Engineer may deem necessary.

REAL ESTATE AND RIGHT OF WAY.

All the land required for pumping stations, reservoirs and right of way, shall be deeded to the city free of charge, together with such fencing and houses for employés as may be deemed necessary by your Engineer.

COST OF PUMPING.

As this item must necessarily enter largely into the cost of supply, we have caused extensive inquiry to be made into this subject, and have the most implicit confidence in the results obtained.

We propose to use the coal from Mt. Diablo mines, which can be furnished at the pumping works at a cost of $5 per ton of 2,240 pounds. We find on investigation that the caloric power of Mt. Diablo coal is such as to require a consumption of three pounds for every horse-power per hour.

To lift 25 million gallons to our Settling Reservoir requires 3,349 33-100 horse-power; hence we find $\frac{3349.33\times24\times3\times5}{2240}=\$538.28$ the cost of engine power per day. The salaries of engineers and assistants, with the cost of oil, etc., will amount to $30, thus making a total expenditure of $568.28 per day, or $207,422 per annum. Add 10 per cent. for wear and contingencies, and the total cost per annum will be $228,164.

To satisfy you that this estimate for pumping is ample, we place in the hands of your Engineer certificates to that effect from parties of the highest professional standing on this coast.

If you entertain any doubt respecting the sufficiency of our estimate of the cost of pumping, we propose to do the pumping for five or ten years for this sum, increased by 10 per cent. as profit, viz: $250,980; and we shall furnish security for its due fulfillment.

It can be seen that the plan of works here submitted has been so designed as to render them entirely beyond the range of accident. Their simplicity is manifest. The entire line is only 84 miles long, consisting of pipe line, reservoir, and dam, and these have been designed with a view to such stability as will insure their safety for all time.

The water we propose to furnish does not depend on the caprice of the seasons for a replenishment. It is taken from the largest supply in the State. The supply is practically inexhaustible.

We shall furnish an extra pumping engine, a telegraph line, and such minor details as your Engineer may require.

Respectfully submitted.

WM. CORCORAN,
For the S. F. and S. J. W. W. Co.

SUPPLEMENTAL PROPOSAL.

We have proposed and we do propose to deliver to the city a complete system of water works, as already described, for the sum of $10,866,000 of the bonds of the city, bearing interest at 6 per cent. per annum, and having 30 years to run.

We now further propose that for and in consideration of the sum of 20 cents per thousand gallons for a period of thirty years next ensuing, we shall construct the works aforesaid and other additional works as the growth of the city may require additional supply, as far as 50 million gallons per day. We shall do all the pumping, we shall pay the interest on the bonds as it may become due and create a sinking fund for their redemption at maturity; and at the expiration of the thirty years aforesaid, we shall give up to the city a system of water works capable of delivering 50 million gallons per day, without cost or charge, and in complete working order. And we shall furnish all the security that may be required for the due fulfillment of our contract.

The advantage of this proposition to the city is apparent from the fact that the consumers are at the present time paying to the Spring Valley Water Company the sum of 75 cents to $1 per 1,000 gallons.

Respectfully submitted.

WM. CORCORAN,
For the S. F. and S. J. W. W. Co.

CITY SERVICE.

We propose to furnish and lay down a city service of 100 miles of pipes, consisting of 10 per cent. of 30-inch pipes, 10 per cent. of 20-inch pipes, 50 per cent. of 12 and 8-inch pipes, and 30 per cent. of 6 and 4-inch pipes, for the sum of $2,500,000. Should you require a greater or less amount of city service than that of 100 miles, we propose to furnish the required quantity in this proportion, and for a proportionate sum of money.

Respectfully submitted.

WM. CORCORAN,
For the S. F. and S. J. W. W. Co.

PROPOSITION OF THE SPRING VALLEY WATER WORKS TO THE WATER COMMISSIONERS.

HON. A. J. BRYANT,
Mayor and Chairman of Public Water Works Commission:

DEAR SIR—In reply to yours of the 29th ult., asking me to communicate in writing to your Commission the terms on which the Spring Valley Water Works will sell and convey to the City and County of San Francisco all of its water, water rights, water works, reservoirs, pipes, and improvements, sources of supply, land and appurtenances, on the penin-

sula of San Francisco, and including the Calaveras property, situated in Alameda and Santa Clara counties, I have to say:

Our company has no desire to sell its property. It owns and controls the only practical system of works and water supply capable of being developed with the growth of the city, even though it should attain a population exceeding five millions. It is reluctant to abandon its well-founded expectations of large prospective profits, to flow from small expenditures, comparatively speaking, in the future. Up to the present time it has received very small returns—not five per cent. per annum on the outlay made for supplying water for three hundred thousand inhabitants. It can now extend its works so as to furnish an abundant supply to a population of seven hundred thousand for less than one-quarter of the expense already incurred.

The existing works are constructed in a most thorough and substantial manner, and are capable of furnishing an average of twenty million gallons daily; while the extensions contemplated by the company, to be completed by the summer of 1881, will supply the city with fifty million gallons daily—enough for seven hundred thousand people—at an expense not exceeding four million dollars. Taking the water from a source which will yield an average daily supply of nearly two hundred million gallons of water, as good as, if not better, than that furnished any city in the United States, and from which one hundred million gallons daily can be brought into the city, in addition to said fifty millions, when required, at a cost not exceeding five million dollars. In short, the Spring Valley Water Works can be put in condition to supply one hundred and fifty million gallons daily by an additional outlay of less than ten million dollars, having still in reserve fifty million gallons daily, which can be utilized at a cost of three million dollars. Whenever the above two hundred millions daily have been utilized and more water is required, which may take place fifty or sixty years hence, our system of works will then have a storage capacity of 77,000 million gallons; they will have been extended sixty miles towards the Sierra Nevada Mountains, and will form the only practical means by which the waters of the Sierras can be supplied to the City of San Francisco.

With all these advantages, you can well understand that the company would reluctantly part with its property at any price; yet its proprietors would not feel willing to see the city saddled with the results that would surely follow the adoption by it of any of the schemes proposed hitherto; such as, for instance, a debt amounting to fully one-third of all its taxable values, and involving, as such an expenditure undoubtedly would, a competition with our company.

Most of our stockholders are citizens and property-owners, and materially interested in all that affects the property of the city. They know, to some extent, what their property would necessarily suffer from the inevitable taxation which would follow the adoption by the city of any of the plans suggested, none of which has or can succeed in gaining the confidence and support of capital.

But the time seems to have arrived when the question is to be submitted to the popular vote whether the City of San Francisco shall or shall not own its own water works and water supply. We occupy a position of divided interest. Being owners of the Spring Valley Water Works, we are also the owners of other valuable interests in the city, and we do not want any act of ours to inaugurate a conflict between the city and our company. We have the greatest confidence in the future of the Spring Valley Water Works. The public are of the same mind, as evidenced by the price of our stock. This confidence is not based upon the small dividends we pay, but upon the great prospective dividends sure to flow from the very small comparative outlay we have to make to amply supply all the future requirements of water by the city. We have been collecting statistics about the cost of water supply for the city since the organization of the company in 1858. We have continuously employed talented engineers who have made the subject of supplying San Francisco with water in the future a special study. We are therefore able to hand you our estimates of the cost of various schemes of water supply now before you for consideration.

I refer to the report of our Chief Engineer, H. Schussler, inclosed herewith, "on the various projects for supplying San Francisco with water," in which he states that to bring

From Clear Lake 50 million gallons daily would cost							$31,909,618
" " 100	"	"	"	"			57,932,538
" Lake Tahoe 50	"	"	"	"			45,670,184
" " 100	"	"	"	"			84,026,449
" Blue Lakes 50	"	"	"	"			41,960,000
" " 100	"	"	"	"			78,897,680
" San Joaquin River 50 million gallons daily would cost							50,000,000
" " " 115	"	"	"	"			80,000,000

If, then, the time has now really come when the city must own its own water works and water supply, this company will consent to sell and convey to it the property referred to in your letter, and consisting of the following:

WORKS AND REAL ESTATE OF THE SPRING VALLEY WATER WORKS.

1. Point Lobos Works, consisting of—

(*a*) Lobos Creek, yielding two and a quarter million gallons per day.

(*b*) Timber dam across creek, about 900 feet from high water mark. *Ft. in length.*

(*c*) Redwood flume, 22 ft. x 19 in. in clear....12,016

(*d*) Tunnel through rocky bluff at Fort Point.... 300

(*e*) Cement pipe, 26 inches in clear.... 8,589

(*f*) Tunnel through Black Point 2 ft. 6 in. x 4 ft. 6. in. clear of brick work, 2,800

Total length of aqueduct.... 23,705 ft.

(*g*) Black Point Pumping Works, consisting of—

Two condensing engines, of 250 horse-power each; four pumps, double-acting, made to run one revolution to the engine, 4 37-100ths.

Size of engine, 40-inch bore, 4 feet stroke;
" pumps, two 14-inch bore, 7 feet stroke;
" " " 12 " 5 "
Capacity of pumps, 75 gallons to each revolution of the engine.

There are four boilers, 52 inches diameter, 15 feet long, 67 3-inch tubes; steam drums, 3 feet diameter, 4 feet high; evaporative power, 10 36-100 lbs. of water for every pound of coal.

Smoke-stack is built square and of brick; is 116 feet high; its inside area is larger at the top than at the bottom—the top being 7½ feet square inside, and the bottom 5 feet.

The engines are so arranged that but one is used at a time, and run by two boilers. In fact, everything is in duplicate, so that in case of any accident the pumps will not have to be stopped.

Engine house, substantial one story and basement brick building, inclosing engines, pumps and boilers.

Suction and screen tank at outlet of Black Point tunnel.

Blacksmith shop, with complete set of tools.

Frame dwelling-house for fireman.

Substantial wharf for landing coal in front of engine house.

Four cast-iron force-pipes from pumps to Russian Hill reservoirs; two 12-inch pipes, 1,010 feet long each, leading to the lower Russian Hill reservoir; and two extra heavy 10-inch pipes, 1,856 feet long each, to the upper Russian Hill reservoir.

2. Pillarcitos Works, consisting of—

(*a*) Pillarcitos reservoir, containing 1,080 million gallons. Area of surface, 115 acres; height of dam, 95 feet above bed of valley; depth of foundation, 46 feet below bed of val-

ley; length on top, 640 feet; width on top, 26 feet; dry slope, 2½ to 1; water slope, average 2¾ to 1, lined with heavy stone.

Dam built in substantial manner of clay put on in thin layers and firmly rolled.

The dam is protected against freshets by two waste weirs: one a tunnel through a rocky spur east of the dam—the tunnel being lined with mason work—two hundred and ten feet long, and mounted at inlet end with brick gate-house, containing three heavy cast-iron gates with brass facings, 4 ft. x 5 ft. in clear. Discharging capacity of waste weir, 650 million gallons per twenty-four hours. The other waste weir is built of heavy timber, at east end of dam, and can discharge 150 million gallons per day.

The dam which originally formed the upper Pillarcitos reservoir is now submerged by the water from the lower. It is built of clay, 35 feet in height, 20 feet wide on top, both slopes 2 to 1, and has a wall of sheet piling through its entire length, and a 12-inch cast iron pipe with gate, as an outlet.

The Pillarcitos main reservoir has as its outlet a gate-house built of stone and brick masonry, containing four cast iron gates with brass facings—this gate-house forming the inlet end of the Pillarcitos aqueduct leading to San Francisco.

(*b*) Feeder to Pillarcitos Lake.

A redwood flume, 42 in. x 16 in. in the clear, and two miles in length, constructed (new) in 1876, of best Humboldt black-heart redwood. It conveys the water from the western slope of the lower Pillarcitos Valley into the reservoir.

This watershed, with the direct shed of the reservoir, contains six square miles of area.

(*c*) Buildings at Pillarcitos: one one-and-a-half story frame building, hard finished—Superintendent's dwelling; two large laborers' boarding houses; one stable, and blacksmith shop; and dwelling for man attending to fences and lands.

(*d*) Pillarcitos aqueduct, commencing at gate-house—mentioned Sub. (*a*),

Tunnel No. 1, bricked, 3 ft. 6 in. x 4 ft. 6 in.	1,550	feet long.
Flume across San Mateo Valley	280	"
Tunnel No. 2, bricked, 3 ft. 6 in. x 4 ft. 6 in., to San Andreas Valley.	3,420	"
Flume, 6 ft. x 24 in.	3,000	"
Main wrought iron 30-inch pipe	66,600	"
Flume, 40 in. x 16 in.	5,300	"
30-inch pipe across Ocean House Road	850	"
Lake Honda tunnel, 3 ft. x 4 ft. 4 in.	2,820	"
Making total length of Pillarcitos aqueduct	83,820	feet,

Consisting of 67,450 feet of 30-inch wrought iron pipe, 7,790 feet of tunnels, and 8,580 feet of flume.

The pipe is made of the best kind of wrought iron, thoroughly coated with asphaltum, and mounted with blow-offs, air-cocks, and self-acting vacuum valves, and is now in good condition and excellent working order.

3. San Andres Works consist of—

(*a*) San Andres reservoir, having an available capacity of 6,690 million gallons, which can be, if necessary, brought to 7,000 million gallons by raising the water 20 inches above the ordinary high water mark.

This reservoir is formed by a dam across San Andres Valley, 93 feet in height above the bed of the valley; its foundation being cut to bed-rock 47 feet below the bed of the valley.

The dry slope is 3 to 1, and the water slope 3½ to 1, and lined with substantial dry stone.

The length of the dam on top is 64 feet; width on top, 25 feet. It is built in the most substantial manner, of clay, spread on in thin layers, thoroughly rolled, rammed and watered.

The surface of the lake has an area of 525 acres at high water mark. The direct watershed of the reservoir is a little in excess of four square miles.

The reservoir is guarded against freshets by a substantial brick tunnel waste weir 520 feet in length, mounted at inlet with a gate-house and four large cast-iron gates, with brass

facings, 3 feet 9 inches x 5 feet each. Its discharging capacity is 500,000,000 gallons per day.

(b) The Locke's Creek aqueduct is a feeder to this lake, taking the water from Locke's and Apanolio creeks, and of the lower Pillarcitos Creek; at each place a substantial stone dam being built across the creek bed.

The entire aqueduct consists of—

Flume 12 in. x 14 in. (feeder from Apanolio Creek)	10,000 feet.	
Flume 16 in. x 32 in. (feeder from Locke's Creek)	15,150 "	
Flume 18 in. x 32 in. (to Locke's Creek Tunnel)	26,500 "	
Flume 32 in. x 60 in. (from Pillarcitos Stone Dam to San Andreas	31,015 "	
Total flume		82,665 feet.
Wrought-iron pipe, 22 in	11,902 feet.	
Wrought-iron pipe, 37½ in	3,718 "	
Total pipe		15,620 "
Locke's Creek Tunnel, lined with brickwork, 3 ft. 6 in. x 4 ft. 6 in. in clear		3,200 "
Total length of Locke's Creek aqueduct		101,485 feet.

Its capacity is 26,000,000 gallons per day.

(c) Another feeder, bringing the water from Pillarcitos and San Mateo creeks, and connecting with the end of the 72-inch x 24-inch Pillarcitos aqueduct, consists of 40-inch flume and 22-inch wrought-iron pipe 7,190 feet long, having a daily capacity of 18,000,000 gallons.

(d) A third feeder is a 22-inch wrought-iron pipe 1,810 feet in length, connecting with the Pillarcitos 30-inch wrought-iron pipe, and discharging into San Andres reservoir, having a daily capacity of 26,000,000 gallons.

(e) Buildings at San Andreas: One hard-finished one and one-half story dwelling for Superintendent, one stable, two boarding-houses, one blacksmith shop.

(f) San Andreas aqueduct, commencing at the gate shaft, about 3,000 feet north of the dam:

38-inch heavy wrought-iron pipe	100 feet.
Brick tunnel, 3 ft. 8 in. x 5 ft., to shaft	285 "
Brick gate shaft, 85 ft. deep and 26 ft in diameter, in clear	26 "
Brick tunnel, 3 ft. 6 in. x 4 ft. 6 in	2,820 "
Wrought-iron 30-inch pipe to San Francisco	63,999 "
Wrought-iron 22-inch pipe to College Hill reservoir	2,850 "
Total length	70,080 "

4. The Crystal Springs Works consist of—

(a) A reservoir called the Upper Crystal Springs reservoir, covering, at 78 feet depth of water, a surface of about 815 acres.

The dam being at present carried to a height of 50 feet above the bed of the valley, has its foundation cut to 98 feet below said bed. Its present capacity is 3,829,674,000 gallons

It will be finished during the coming summer to a height of 83 feet, and containing, with a depth of water of 78 feet, 9,426,400,000 gallons.

Its crest will have a width of 30 feet and a length of 560 feet when finished.

The dry slope is 3 to 1 and the water slope 3½ to 1, and lined with a heavy dry stone pitching.

The outlet of the reservoir consists of a mason-work tunnel, 780 feet in length, through the bluff on the east end of the dam, having a vertical brick inlet chimney 15 feet in height at its inlet, and a ¼-inch wrought-iron pipe 52 inches in diameter, built in the mason-work in the upper 420 feet to the Center Gate Shaft, which goes to the surface, is 85 feet deep and lined with masonry, where the pipe can be shut off by a heavy cast-iron brass-faced 42-inch water-gate. From here a pipe 355 feet in length and 42 inches in diameter leads

through the balance of the tunnel, leaving a space between the outside of the pipe and the mason-work for a man to pass in and out of the tunnel.

(*b*) This pipe will be continued twenty miles in length to San Francisco, where the water will arrive at an elevation of about 175 feet, and supply the entire lower portion of the city.

The watershed draining directly into this lake contains fifteen square miles. The dam is at present guarded against freshets by a substantial timber waste weir, having a heavy brick-work foundation for its crest, and capable of carrying 2,000 million gallons in twenty-four hours.

(*c*) Buildings at Upper Crystal Springs dam consist in laborers' boarding and sleeping house, substantial stable for one hundred and forty horses, and a blacksmith shop with a complete set of tools.

5. The San Francisco Reservoir and Pipe system consists of—

(*a*) Seven reservoirs, of the following elevations, sizes, and capacities:

	Depth.	Elevation	Capacity, Gallons.	Character of Work.
Lake Honda Reservoir.......	29 feet.	377 feet	32,918,000	Heavy masonry and wall through center.
Upper Russian Hill Reservoir	22 "	306 "	3,724,000	Clay embankment lined with brick work. Brick partition through center.
Clay Street Hill Reservoir...	9 "	375 "	141,000	Redwood.
Lower Russian Hill Reservoir	14 "	139 "	6,712,000	Clay embankment lined with brick work. Brick partition through center.
College Hill Reservoir.......	18 "	252 "	15,006,000	Clay embankment lined with heavy stone pitching.
Market Street Reservoir.....	15 "	196 "	2,250,000	Heavy masonry, partition wall through center.
Brannan Street Reservoir....	8 "	85 "	400,000	Heavy masonry.
Total capacity.....	....	....	61,151,000	

(*b*) Pipe system in City of San Francisco. The Lake Honda Main Conduit consists of—

(1) 2,572 feet of 30-inch pipe from screen tank at the main tunnel to outlet of lower tunnel, where it is joined by a 16-inch cast iron pipe from the bottom of the lake through the lower tunnel, and continues 22 inches in diameter to the city, being 3,744 feet of heavy wrought-iron pipe and 8,903 feet of extra heavy 22-inch cast-iron pipe to the junction of Haight street and Fillmore, where it branches into one 16-inch and 12-inch pipe, having previously branched at Devisadero street into a 12-inch pipe.

(2) The College Hill distributing main pipe connects with the main San Andres pipes at the junction of Courtland avenue and Mission road; thence along the Mission road to Valencia and Market, to Sansome, as follows:

2,500 feet of 22-inch wrought-iron pipe to a point 1,044 feet south of the south line of Twenty-fifth street; thence along Valencia 798 feet of 22-inch cast-iron pipe, to where it branches into one 20-inch cast-iron pipe, which, after running 208 feet, reduces to 16 inches along the west side of Valencia, the other branch being 22-inch cast-iron for 48 feet; thence along east side of Valencia, heavy wrought iron pipe 9,097 feet, to Market and Potter; thence heavy cast-iron 22-inch pipe 8,009 feet along south side of Market to Sansome, having branches at every street.

Inclusive of the above named Lake Honda and College Hill Mains, the pipe system, as

laid and connected in the streets of the City of San Francisco, consists of the following lengths of pipes, of various sizes:

2,572 feet 30-inch heavy wrought.
15,341 feet 22-inch heavy wrought.
17,896 feet 22-inch cast—or 33,237 feet 22-inch in all.

20-*inch.*	16-*inch.*	12-*inch.*	10-*inch.*
1,202 feet.	23,694 feet.	61,511 feet.	11,293 feet.
8-*inch.*	6-*inch.*	4-*inch.*	3-*inch.*
154,083 feet.	263,784 feet.	240,842 feet.	88,159 feet—together with the pipe on hand.

The following is a list of the real estate and water rights in San Franciaco, Marin, San Mateo, Alameda and Santa Clara Counties belonging to the Spring Valley Water Works:

I. That certain tract, piece, or parcel of land situate, lying, and being in the City and County of San Francisco, in the State of California, commonly known as and called the "Francisco street or Lower Russian Hill Reservoir property," consisting of fifty-vara lots numbered one thousand one hundred and sixty (1,160), one thousand one hundred and sixty-one (1,161), one thousand three hundred and forty-six (1,346), one thousand three hundred and forty-seven (1,347), one thousand four hundred and thirty-five (1,435), one thousand four hundred and thirty-six (1,436), forming and constituting the block bounded by Francisco, Hyde, Bay, and Larkin streets, in said city; also, fifty-vara lots numbered one thousand two hundred and fifty-two (1,252), one thousand three hundred and forty-five (1,345), and one thousand four hundred and thirty-four (1,434), constituting and forming the northerly half of the block bounded by Chestnut, Hyde, Francisco, and Larkin streets, in said city.

II. That certain tract or parcel of land, situate, lying and being in said City and County of San Francisco, commonly known and called the "Lombard street or Upper Russian Hill Reservoir property," consisting of the six fifty-vara lots numbered respectively seven hundred and seventy-six (776), seven hundred and seventy-seven (777), seven hundred and seventy-eight (778), seven hundred and seventy-nine (779), seven hundred and eighty (780), and seven hundred and eighty-one (781), and forming the block bounded by Greenwich, Hyde, Lombard and Larkin streets, in said city.

III. That certain piece or parcel of property situate, lying, and being in the said City and County of San Francisco, commonly known as and called the "Black Point Pumping Works," consisting of fifty-vara lot number three (3), in block number thirty-seven (37), and fifty-vara lot number four (4), in block number thirty-eight (38), in the Western Addition to the said City of San Francisco, according to the official map thereof, together with all the machinery connected therewith and the wharf in front thereof.

IV. Fifty-vara lot No. 6, in block 28, Western Addition.
" " 804, " 293, of the city.
" lots Nos. 2, 3, and 4, in block 29, of the city.

V. Block 65 entire, in New Potrero, bounded by Sixteenth street, Santa Clara street, Potrero avenue, and Jersey street.

VI. Office property on California street, 22 feet 3 inches by 137½ feet, with office building No. 516 California street.

VII. The property commonly known as the "Clay street Hill Reservoir," consisting of fifty-vara lot number eight hundred and twenty-eight (828), in said City and County of San Francisco.

VIII. That certain piece or parcel of property situate, lying, and being in the City and County of San Francisco, commonly known as and called the "Market Street Reservoir Property," described as follows, to-wit: Commencing at the south-east corner of Church and Kate streets; thence along southerly line of Kate street easterly 694 feet 6 inches; thence at right angles southerly 351 feet to the northerly line of Market street; thence along this line in a south-westerly direction 372 feet 5 inches to a street (name unknown); thence along the north line of this street south 85° 30′ west 143 feet; thence north 52° 30′ west 175 feet; thence north 52° west 100 feet; thence north 45° 30′ west 45 feet; thence north 36° west 38 feet; thence north 23° 30′ west 59 feet; thence north 10° 15′ west 8 feet to the easterly line of Church street; thence north 5° 45′ west 205 feet to the place of beginning, containing 7 4-10 acres, more or less.

IX. Also lot on south-east corner of Kate and Buchanan, 25 feet on Kate street by 100 feet on Buchanan.

X. That certain other piece or parcel of property, situate in said City and County of San Francisco, commonly known as and called "the College Hill Reservoir Property," consisting of a tract of land five hundred and thirty-four (534) by six hundred and forty (640) feet, situate at the north-west corner of West avenue and Park streets.

XI. That certain other tract or parcel of land situate in said City and County of San Francisco, commonly known as and called "the Lake Honda Reservoir Property," consisting of about sixty-three acres of land, and described as follows: Commencing at corner-post number 24, which stands at the junction of courses 24 and 25 of the San Miguel Ranch survey, as surveyed by the United States Surveyor-General: running thence north 55° 30 east seven (7) chains and twenty (20) links; thence south 44° 30′ east twenty-five (25) chains and thirty-four (34) links, thence south 75° 30′ west sixteen (16) chains and sixty (60) links to a post marked "A"; thence north 44° 30′ west thirteen (13) chains and twenty-four (24) links; thence north 18° 30′ east eight (8) chains and ten (10) links to the place of beginning, being the main "Lake Honda Reservoir Tract," and containing 29 1-10 acres.

Also commencing at the same corner-post, No. 24, and running thence north 45° 30′ east eleven (11) chains and thirty (30) links; thence north twenty-two (22) chains and sixty (60) links; thence south 89° 15′ west eleven (11) chains, more or less, to a fence; thence south thirty-six (36) chains and seventy-nine (79) links; thence north 18° 30′ east eight (8) chains and ten (10) links to the place of beginning, containing about thirty and one-half acres, and designated as the waste pond.

Also commencing at a point on the southern boundary of the reservoir tract proper, being one (1) chain and sixty-six (66) links, more or less, from the corner-post marked "A" above mentioned; thence running north 75° 30 east three (3) chains; thence south 12° 15′ east nine (9) chains and thirty-six (36) links; thence south 75° 30′ west three (3) chains; thence north 12° 15′ west nine (9) chains and thirty-six (36) links to the place of beginning, containing two and eight-tenths acres, and designated as the tunnel outlet tract.

Also commencing at the centre line of the main Lake Honda Tunnel (2) two chains northerly from the inlet or south end of said tunnel; thence running north 65° east seventy-seven and one-half (77½) links; thence south 8° 15′ west seven (7) chains and nine (9) links to the middle of the creek; thence south 65° west one (1) chain and fifty-five (55) links along the centre of said creek; thence north 8° 15′ east seven (7) chains and nine (9) links; thence north 65° east seventy-seven and one-half (77½) links to the point of beginning and designated as the tunnel inlet tract, containing one acre.

XII. That certain other piece or parcel of land situate in the City and County of San Francisco, commonly known as and called "the Lobos Creek Property," containing twenty acres, and described as follows:

Commencing at a stone monument bearing south 66° 15′ west nine chains and eight links (9.08) from the inlet end on the border of Mountain Lake, and known as the Hotalling

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Tunnel, the said monument marking the south-east corner of a strip of land (3) three chains and eighteen (18) links wide, following the meanderings of Lobos Creek, and including both banks thereof, from its head to its mouth at the ocean.

XIII. Also those certain other tracts or parcels of land in the County of Marin and the old town of Saucelito, to-wit:

Lots 8, 9, 10, 11, 12, 13, and 14,	in Block 6, Old Saucelito.		
" 16 and 17,	" 10, "		
" 6, 7, 16 and 17	" 14, "		
" 3, 4, 5, 11, 12 and 13,	" 16, "	with valuable springs thereon.	

XIV. All that certain tract, piece or parcel of land situate, lying and being in the County of San Mateo, and State of California, commonly known as and called the "Spring Valley Farm," being a tract of land containing about 5,181 acres, more or less, embracing the Pillarcitos Reservoir and the contiguous portions of the watershed, and embracing the whole of sections twenty-nine (29(, thirty (30) and thirty-two (32), and parts of sections nineteen (19), twenty (20), twenty-eight (28), thirty-one (31), thirty-three (33) and thirty-four (34), in Township four (4) south, Range five (5) west, Mount Diablo base and meridian; parts of sections three (3), four (4) and five (5), in Township five (5) south, Range five (5) west, same base and meridian; and parts of sections twenty-two (22), twenty-three (23), twenty-four (24) and twenty-five (25), in Township four (4) south, Range six (6) west, same base and meridian.

XV. Also, all the water rights of "Locke's Creek," so-called, with the tributaries thereof, the same being a feeder of said Spring Valley Reservoir, with the flumes, pipes and aqueducts now, or which may hereafter be, used in the diversion, appropriation and conversion of said waters to the uses of said corporation, and the lands belonging thereto, being parts of sections five, six, eight and nine, Township five south, Range five west, containing 933 acres.

XVI. All that certain other tract or parcel of land, situate, lying and being in the said County of San Mateo, commonly known as and called the "San Andres Reservoir Tract," containing about sixteen hundred (1,600) acres of land, embracing the San Andres Reservoir and the contiguous portions of the watershed.

XVII. All that certain other real estate, situate, lying and being in the said County of San Mateo, commonly known as and called the "Crystal Springs Reservoir Tract," being the reservoir now in course of construction in the said County of San Mateo, and embracing the following tracts of land now owned by the Spring Valley Water Works, to-wit: The Sawyer Tract, of two thousand two hundred (2,200) acres; the Spaulding Tract, of forty-four and 95-100 acres; the Mauvais Tract, of thirteen (13) acres; the Crystal Spring Tract, of ninety-five and 14-100 acres; the Carey Tract, of one hundred and thirty-five and 74-100 (135.74) acres; the Arguello Tract, of five hundred and sixteen and 43-100 (516.43) acres; the Dolan Tract, of seventy-one (71) acres; the Peyton Tract, of four hundred and fifty-two and 74-100 (452.74) acres; the Bollinger Tract, of one thousand one hundred and seventy-one and 78-100 (1,171.78) acres; the O'Callaghan Tract, of six hundred and fifty-nine and 30-100 acres (659.30); the Maynard Tract, of four hundred and ninety-six (496) acres; and the Rowe Tract, of one hundred and two 78-100 (102.78) acres—containing in all 5,958.87 acres. And also all the land which may be hereafter acquired for the construction and protection of said Crystal Springs reservoir, and all the water rights which have been or may be hereafter acquired for the supply thereof.

XVIII. All those certain other tracts or parcels of land, situate, lying, and being in the said county of San Mateo, known, bounded, and described as being the southwest quarter, the west half of the southeast quarter, the south half of the northeast quarter of the frac-

tional north half of the northeast quarter, and the fractional northwest quarter of section eighteen (18), and the fractional southeast quarter of section seven (7), all in Township four south. Range five west (T. 4 S., R. 5 W.), Mount Diablo base and meridian, containing five hundred (500) acres of land, more or less.

XIX. All the right, title and interest of the Spring Valley Water Works, of, in, and to all the waters of the San Gregorio Creek. the Tunitos Creek, the Purissima Creek, and the Pescadero Creek, in the said county of San Mateo, and the tributaries and feeders thereof, with all the right which the said Spring Valley Water Works now has, or may hereafter have, to divert the same, and appropriate the same to the uses and purposes for which said Spring Valley Water Works is incorporated.

XX. All those certain other tracts, pieces, or parcels of land, and all those waters and water rights, situate, lying, and being in the counties of Santa Clara and Alameda, in the State of California, forming and constituting the site for what is known as, and designed to be, the Calaveras reservoir, being a new reservoir, the construction of which the Spring Valley Water Works has now commenced, and which, when completed, will be the largest in capacity and supply of all its system of works, the said property being all those tracts and parcels of land, and waters and water rights recently purchased by the Spring Valley Water Works from the Alameda Water Company, and from others in said counties, and being bounded and described as follows:

The south half of the southwest quarter of section eleven (11); all of section thirteen (13); the south half and the south half of the north half and the north half of the northwest quarter and the northwest quarter of the northeast quarter of section number fourteen (14); the west half of the southwest quarter of section number fifteen (15); the southeast quarter of the southeast quarter of section number sixteen (16); the northwest quarter of the northwest quarter, and the east half of the northeast quarter, and the southwest quarter of the northeast quarter of section number twenty-two (22); the east half of the east half, and the west half of the northeast quarter, and the northwest quarter of the southeast quarter, and the north half of the northwest quarter of section number twenty-three (23); all of section number twenty-four (24); all of section number twenty-five (25); the southeast quarter and the south half of the northeast quarter of section number twenty-six (26); the north half of the northeast quarter, and the north half of the south half of the northeast quarter, and fraction of south quarter of northeast quarter of section number thirty-five (35); and the north half of the north half and fractional south half of the north half of section number thirty-six (36); all in Township number five south, Range number one east, Mount Diablo base and meridian; also the fractional northwest quarter of section number thirty-one (31) in Township number five (5) south. Range number two (2) east--same base and meridian; containing four (4,000) thousand acres of land, more or less.

Also, all the waters, water rights and water privileges owned or held or which may hereafter be acquired by the party of the first part, of, in or to the waters of the Alameda Creek, and all the rivulets, streams, springs and feeders thereof, with the right forever to divert the same at the point where the Spring Valley Water Works is now about constructing a dam and reservoir for said waters, and to convert the same to the uses and purposes of said water works: said right including the right now held by the said Water Works to take and appropriate the waters heretofore used for the motive power of the Vallejo Mills, in said county of Alameda, so far as they can be taken at the point of appropriation aforesaid, and forever to divert the same at the point aforesaid from said mills; also including all the riparian rights now held by said company, or which it may hereafter acquire, as against any and all owners of the soil bordering upon said stream below the point of diversion aforesaid.

XXII. Also all the reservoirs, pipes, flumes, aqueducts, mains, service pipes, and all the personal property of said Spring Valley Water Works, of every description.

And now as to the price. The company has no desire to take any advantage of the necessities of the city; in proof of which assertion I refer to the course it has pursued during the municipal litigation forced upon it for the past eight years.

The amounts that we have expended in the conduct of our business, with legal interest added from the time of the expenditure, less the dividends paid to our stockholders, aggregate more than $19,000,000, as can be easily verified by a competent accountant, to whom, at your request, a full exhibit of our books and affairs will be made.

But, under the circumstances, I am authorized by our Board of Directors to say that we will sell and convey all our property, as aforesaid, to the City and County of San Francisco for $16,000,000 in gold coin.

Very respectfully yours,

CHAS. WEBB HOWARD,
President of the Spring Valley Water Works.

San Francisco, February 28, 1877.

PROPOSITION OF P. DONAHUE, SOL. A SHARP, AND DAVID MAHONEY.

To the Mayor, Auditor, and District Attorney of the City and County of San Francisco:

Gentlemen—In compliance with your request of the 29th of January we submit to you the following propositions:

First—We will bind ourselves to furnish reservoirs of capacity of forty millions of gallons, to erect full and complete works of capacity of ten millions of gallons per day, and lay down pipes through the city to the extent of thirty miles, for the sum of four millions of dollars, six per cent. City Bonds.

Second—We will furnish the same as above provided for, except the distributing pipes, and extend the pipes to the New City Hall for the sum of three million three hundred thousand dollars, six per cent. City Bonds.

N. B. All the above works shall be complete, and approved of by the engineer appointed by your Honorable Body.

Third—We will sell to the city the lake and a thousand acres (reserving eight acres) south of the Ocean House, for the sum of two million seven hundred and fifty thousand dollars.

In all the above propositions it is proposed to put in the thousand acres of land, exclusive of the lake.

Respectfully yours, etc.,

P. DONAHUE,
SOL. A. SHARP,
DAVID MAHONEY.

PROPOSITION OF THE FEATHER RIVER WATER COMPANY.

To the Honorable Board of Water Commissioners, San Francisco:

Gentlemen—The Feather River Water Company propose to furnish to the City and County of San Francisco pure fresh water in such quantities as your Honorable Body may determine to be needed for the present and future wants of this municipality.

Such supply to be measured simply by the requisition your Honorable Body may make upon the illimitable resources, which this Company offer to place at the disposal of such agents of the City and County as are now and who may hereafter be selected to determine upon the quantity needed.

This company, in the presentation of its plans for your consideration, suggests that it deems it appropriate to present results, leaving all questions of detail for consideration hereafter.

SUPPLY.

We call your attention to the sources of our supply. One of the chief sources of water supply of the Feather River Water Company is as follows:

The North Fork of the Feather River and its tributaries, the central reservoir of which is in the Big Meadows, in the Sierra Nevada range of mountains, the watershed of which we present at 1,000 square miles and over.

QUANTITY.

This supply is so abundant that we hardly anticipate criticism, much less doubt, on the part of any person acquainted with the territory from which the supply is taken.

We can but regret that the lateness at which the proposition of this company was presented to your Honorable Body has prevented, on your part and that of your Engineer, a thorough and complete examination into the properties offered, and hereinafter referred to.

The Big Meadows is a great natural artesian reservoir lying at the base of Lassen s Peak, a snow-capped mountain eleven thousand (11,000) feet high, the immediate streams flowing from which are never fordable, can only be crossed by bridges or boats, and will float the largest vessel which ever entered the harbor of San Francisco. Therefore this source will last as long as this monarch of the mountains shall pierce the cloud-banks that here make the Sierras their great and favorite resting beds. A mountain where, from its summit and slopes, trickle down living streams of water—the melting of the banks of eternal snow—the accumulated stores of centuries, that are but too inviting to the thirsty City of San Francisco, surrounded by seas of water, and having but metered drops to drink.

This watershed has an average annual rainfall of 100 inches (which statement we make upon the authority of Professor Davidson, of the Coast Survey), falling upon a geographical formation covered by dense forests of sugar and other varieties of pine timber, no cultivation or habitation thereof, and that is well calculated to store and to let down the largest quantity of water that San Francisco can possibly consume for centuries to come.

This is the locality where the Coast and Sierra Ranges of mountains seem interlocked and receive the immense cloud formations which here deposit and store and bank themselves up as a future treasure, in the forms of both snow and rain, and upon which San Francisco can safely draw her drafts, with no fear of their ever being dishonored.

Professor Davidson is our authority for informing your Honorable Body that in the central and southern portions of the great valley of the Sacramento, particularly the latter, the average rainfall is barely sufficient for the maturing of crops. In the northern part of the State, however, this is reversed; the rainfall is generally more than sufficient, rendering even reclamation and drainage necessary; that on the flanks of the mountains, along the Sierras and Coast Ranges, and especially to the north, the rainfall is very large, and on

the average in the Sierras there is a superabundance of water. But even in the Sierras, where nature stores away about sixty-six feet of snow annually for future consumption, she only stored away last winter about eight feet, which fact renders it quite probable that no springs will break out in this State in September next at the places where they usually do, and least of all, in our judgment, upon this Peninsula.

On the question of water supply and quantity, therefore, we take it for granted that your Honorable Body will doubtless take this important meteorological fact into due consideration, and that you will begin where your predecessors left off, and profit by their experience—whether their work was well or illy done, or whether it blessed or cursed those who had to pay for it.

Their mistakes on this all-important want to our young but rapidly-growing metropolis, should prove your instruction—their failures, your admonition.

QUALITY.

This water is cold as ice, clear as crystal, and so pure that it needs not a chemist to analyze it at any price.

ONE OF THE MEANS OF CONDUCTING THE WATER.

We propose to take the waters from the Big Meadows, at the junction of Warner's Creek with the North Fork of the Feather River, and by a canal thirteen miles long, and with a capacity of 100,000,000 gallons per day, and with a fall of 6.40 feet per mile, to be constructed in accordance with the specifications furnished by your Engineer, Colonel Mendell.

This canal, by a survey made upon the ground, courses along the southern base of Stover's Mountain, and conducts these waters into the valley of "Lost Creek," where a reservoir site of 5,000 acres is established. Thence by the natural bed of Lost Creek to Deer Creek Meadows, where another reservoir site of 2,000 acres is established. Thence by the natural bed of Deer Creek to a point 1,150 feet above the level of the sea. Thence by a similar-sized canal to a point in Township 21 north, Range 3 east, Mount Diablo base and meridian, and having an elevation of 977 feet above the level of the sea, where we reach the head of our pipe line, situate upon one of those long spurs that here make down from the main Sierras into the Sacramento Valley.

In this vicinity and immediately opposite thereto, we have by a careful examination and survey made by this Company, delineated the peculiar formation and location of the spurs which make down and border upon the southern bank of Stony Creek, and which afford us one of the shortest pipe lines that can span the Sacramento Valley.

From this spur of the Sierras we pipe the waters to a sufficient altitude upon a corresponding spur on the Coast Range.

On the other hand, we can take up the pure waters of the numerous and bountiful tributaries of the North Fork of the Feather River, at a lower elevation above the sea, and conduct said waters to the head of our pipe line *via* the reservoir at Yankee Hill, or *via* Concow Valley to the same point.

These tributaries upon which no mining is, or ever was, or ever will be done, have as their source of supply a watershed of 1,000 square miles, covered with numerous lakes, similar to the Upper Big Meadow supply, and flow through a decomposed granite formation, rendering canal construction easy, and maintaining the water in its state of absolute purity.

The only growth on this entire watershed is the pine and oak timber—no cultivation—no habitation.

The head of our canal line on the Coast Range is 697 feet above the level of the sea, from which point said canal courses along the most eastern slopes or faces of the Coast Range (for you will now observe that this range has a peculiar sloped watershed) to a point where

nature furnishes us with a reservoir site of ten square miles, called "Upper Little High Valley." A canal leads to another reservoir site of eight square miles, called "Lower Little High Valley." Here nature, as if in a spirit of excessive bounty, successfully aids our plans by having scooped out of the Coast Range one of the most magnificent rock-bound basins to be found in our mountains, and which is called "Bear Valley," and of 40 square miles in extent, and which we have selected as another reservoir site.

In addition to this, we avail ourselves of Indian Valley for a new store of water, coming as it does, from an immense watershed, rising in places to 4,000 feet above the level of the sea, and conduct these waters from the Indian Valley basin through the Kanawha Pass into our main canal; thus we have in connection with our pipe and canal line—not simply a system of reservoirs, but in fact a chain of large lakes; and, as startling as the statement is, these reservoirs have a superficial area greater by 16 square miles than the entire superficial area of Clear Lake—a lake, had the waters of which not been unfortunately deemed impure, all persons admit would have been an available source of supply for San Francisco.

Thus we have stored up for actual use in the event of need, in a complete system of reservoirs, an abundance of water, and with a depth of 50 feet and upwards—the area alone of which does not fall much below the entire watershed of the Peninsula plans and which reservoirs will store, in the event of any accident which the imagination of the most skeptical engineer can picture, equal to a six years' consumption of 100,000,000 gallons daily for the people of San Francisco.

It is not improbable that our perfected survey, now in process, will enable us to locate a shorter and more favorable pipe-line across the upper Sacramento Valley, due to the fact that the spurs that here make down from the Sierra, recommend themselves to us as equally, if not more favorable, and which will enable us to pipe across the Sacramento Valley under a less pressure—save 10 or more miles of pipe, and reach a higher elevation on the Stony Creek spurs—in which event canaling along Indian Valley on its east side would be easy, and thus enable us to fill Bear Valley Reservoir direct from Big Meadows—thus leaving our system of reservoirs as heretofore described, intact, simply changing the mode of storing them with water.

From this system of reservoirs our canal follows down the natural bed of Bear Valley Creek, which upon examination and survey, we find admirably adapted for the purpose, for a distance of 12 miles to a point near its junction with Cache Creek. From this point we have (2) two lines depending upon many facts, among which is, whether an additional reservoir site between Cache Creek and Saucelito is needed. Should we need it, or should your Honorable Body deem it desirable, then we propose making available Puta Creek and its immense watershed, the waters of which, by Scowden's report, are purer than any he examined and reported upon, and storing its waters in a proposed Berryessa Reservoir, and by a canal, come down to Napa, by a line delineated in detail on our map, and by means of a short tunnel above Knoxville, or we course along the east face of the Coast Range, and reach Napa Valley by a similar line. Our perfected surveys will disclose the better of these two routes. Once on the high hills bounding Napa Valley on the east, we pipe across said valley by a line four miles long, when we again take up our canal line to a point above the town of Sonoma, where we again have 1½ miles of pipe; thence by canal to the point where we pipe by five miles, to the high ground north of Petaluma, whence we canal direct to Saucelito. Thus, on our whole route we avoid all swamp, overflowed, salt marsh and tide lands, and have firm and dry ground for our pipes, and in the several structures requisite we follow and comply with the specifications as furnished us by your engineer.

This line then brings us to Saucelito, from which point we cross by tunnel under Golden Gate to San Francisco. Up to Saucelito, the several hydraulic and hydrostatic problems that enter herein for solution do not differ materially in principle from those that must perforce enter into any one of the Sierra Nevada plans, and need not here be more minutely discussed than in the manner set forth.

Our plan therefore presents the special problem of crossing by a tunnel under the Golden Gate. To this subject our engineers have devoted themselves with a care that renders it, in our opinion, safe, and to the extent of making the following proposal, to wit:

I. The Feather River Water Company propose to build and construct the tunnel line from Saucelito to San Francisco, without asking or expecting a dollar to be paid or a bond to be issued until your Engineer and Commission, or your successors, can inspect the same and know that it is complete and perfect.

II. We propose, if the contract is awarded and ratified by a popular vote, to give a bond in such sum as your Commission may designate for the faithful performance of this part of the work of construction, as well as the other part of the work of construction.

III. And whereas, a special election, such as is contemplated by the law creating the Water Commission, will be held at the expense of the City and County of San Francisco, and will without doubt cost $30,000—we propose, if your Commission will award the contract to us, to enter into a bond with good and sufficient sureties, conditioned to the effect that if the Feather River Water Company, its successors or assigns, do not enter into such a required bond within thirty days from the date of the ratification by the people, and do not enter upon the work of constructing the tunnel, to pay to said City and County of San Francisco the cost of holding such special election, not exceeding the said sum of $30,000 specified in said undertaking.

This tunnel under Golden Gate, when successfully constructed, will be a property in which not only the City of San Francisco and State of California will have an interest in more ways than one, but in our judgment will be a matter which the nation will regard as of no minor consequence in connection with the defenses of this harbor and of the City of San Francisco. But however important these matters may hereafter prove, our consideration thereof for the present is limited to its relation to the water supply of this Ctty. This tunnel once constructed, opens up an entirely new chapter for an ample water supply for this City, and enables and compels your Honorable Body to study it in the light of new sources and watersheds hitherto neglected, and not presented to your Honorable Body, so far as we are informed, outside of the presentation thereof by the Feather River Water Company. The full and careful consideration that we have been able to give this subject by surveys, examinations and proper compilations of maps, has already cost our Company a very large outlay of money—and here we take the liberty to call the attention of your Honorable Body to a fact, important to us if not to the public, that in nearly all, if not all, the plans proposed to your Honorable Body the public of San Francisco have incurred and paid large expenditures in various ways, and that, so far as we know, they have not as yet spent a single dollar to aid in any way our plans, or to collect data in connection therewith that would guide your action, or assist your deliberations to form a just judgment in this important matter. We therefore, in successfully solving the problem of a tunnel construction under the Golden Gate, and thus, by introducing you and the public to these new sources of water supply, do not feel justified in leaving our rear unguarded by permitting other parties to procure and furnish a supply from this new field, and therefore call your attention to this fact, to-wit: If you draw a direct line from Saucelito to the Big Meadows, and thence another line to the mouth of Eel River, which we have done upon a map of the State, and which we now show you, it will be perceived that we have a new watershed, shaped like a fan, having for its boundary the Pacific Ocean. We aver that the rainfall within the boundaries so described, exceeds by far the rainfall of any other equal-sized area in the State of California. A knowledge of this fact, and relying upon it and other data collected by us in the study of the question of a proper water supply for San Francisco, warrant the Feather River Water Company therefore in pointing out, as they now do to your Honorable Body, an additional source of supply, in the event that neither of the other proposals hereinbefore referred to shall be by you accepted.

EEL RIVER.

After the F. R. W. Company had demonstrated by its engineers the feasability and practicability of constructing a tunnel under the Golden Gate, it was deemed necessary to make an examination into other sources of water supply, which might be available to San Francisco from the waters of Marin, Sonoma and Mendocino Counties lying west of the dividing slope of the Coast Range. We think that such sources exist in the Middle and South Fork of Eel River in Mendocino County, the waters of which, upon a survey and measurement thereof made by one of the engineers and surveyors of this company (Mr. Benson), were found capable of furnishing 200,000,000 gallons daily to the city.

We propose to divert the waters of Eel River at a point 2,000 feet above the level of the sea, and by canal carrying 100,000,000 gallons daily, and constructed in accordance with the specifications of your engineer, conduct the same to the extreme west face of the Coast Range. Once on said west face, the canal would keep on high firm ground, through a country well timbered and tapping the heads of all the numerous streams which rise in this Range and debouch directly into the ocean. A canal line thus established would not lose water by evaporation, as evaporation would be amply compensated for by the contributions of numerous small feeders along the entire length of this proposed route. In addition to this, the country through which the canal would pass is cool in summer, subject to fogs from the ocean for a considerable portion of the year, thus maintaining the water in a state of freshness and purity.

Should it ever be found necessary, the waters of the South Fork of Trinity River could be conducted to the head of the proposed canal, and which distance is over easy ground and will not exceed 25 miles in length.

Or again, an interior route for the canal could be selected by means of a tunnel three-fourths of a mile long in the mountains which separate the waters of Eel from those of Russian River, and bring us down into the broad basin of Russian River, and which last named river could be thus made available.

On either of these two routes we have estimated that the pipe line would not exceed 12 to 15 miles in length.

The interior route would not be as favorable as the Coast route, due to the fact that the evaporation thereon could not be compensated for to the same extent as on the Coast route, owing to the absence of fogs, and also from the further fact that most of the small streams which have their sources on the eastern slope of the mountains dry up in the summer season. The length of canal by either route will be about 200 miles.

The great advantage which this line possesses is, that it is practically without pipes and does not involve the expensive elements of pumping, and affords numerous reservoir sites along the heads of the many streams *en route.*

QUALITY.

As to the purity and quality of the water there can be no question, rising in and flowing through a non-mineral formation, and its source derived from the region of almost perpetual snow in the Yallo-Balley Mountains at an elevation of 4,000 feet above the level of the sea.

SERVICE SYSTEM.

As to the service system so styled by Mr Schussler, Chief Engineer of the Spring Valley Water Company, as belonging to Spring Valley, and included in the millions which it asks for its properties, we say that if the Commission will adopt such a suicidal plan as to accept pipe of equal dimensions, we will undertake to furnish and lay down an equal amount of water pipe, of equal quality, weight and durability, for the sum of $1,650,000.00.

But for a proper service system, for one which the city will not be compelled year after year to be changing and to be at considerable expense annually in removing and extending, we cannot undertake to give any estimate until your Commission shall have obtained from your Engineer, Col. Mendell, and give public notice of the same, specifications as to the number of miles, thickness, diameter and kind of pipe, and where to be laid.

The distinguished engineer of Spring Valley lays great stress upon the service system belonging to that corporation.

We assert that if the officers of the Fire Department be called here and sworn, we will undertake to prove to your Honorable Body that the present system is utterly and thoroughly insufficient in the greater portion of the city.

We here assert that some of the most valuable property in the city is situate along the following named streets, which streets have the sizes of mains set opposite to them, respectively, and to any one acquainted with the city the insignificant protection which is thus afforded is apparent at a glance, and cannot be confused or confounded by scientific or abstract calculations made by ever so distinguished a Civil and Hydraulic Engineer.

TABLE OF STREETS.

Streets.	*Size of Mains.*
Montgomery, Market to Jackson	8 inches.
Sansome, " to Bush	8 "
" Bush to Pacific	6 "
Battery, " to Jackson	8 "
Front, Market to Vallejo	6 "
Davis, Pine to Sacramento	4 "
Drumm, Market to Clay	6 "
Sutter, Dupont to Kearny	4 "
" " to Taylor	6 "
" Larkin to "	4 "
Stockton, Market to Sutter	6 "
" Bush to "	3 "
" " to Washington	5 "
Second, Market to Folsom	6 "
Third, " to Brannan	8 "
" Berry to "	4 "
Fourth, Market to Berry	6 "
Fifth, " to "	8 "
" Bryant to "	6 "
Sixth, Market to Folsom	6 "
" Bluxome to "	4 "
Steuart, Market to "	4 "
Washington, Battery to Powell	6 "
Clay, " to East	4 "
Commercial, Kearny to "	4 "
Sacramento, Hyde to Front	4 "
California, Powell to Dupont	4 "
Pine, Mason to Kearny	4 "
" Battery to "	6 "
" " to Front	4 "
Post, Powell to Hyde	4 "

The service system of Spring Valley so-called, and which Engineer Scowden in his elaborate report designates the "Distribution System of the City," includes, as we are informed,

the "Systems" constructed by the Ensign & Bensley companies and the present corporation, the greater portion of which is 3, 4, 6 and 8-inch pipe.

This "System," which all companies now proposing to furnish water to the city are confronted with as a "scare-crow" to keep them out of the field of competition, was no doubt a good one when our city was sparsely populated; when the "International Hotel," then on Jackson Street, was a structure of immense capacity and the first-class hotel of San Francisco, and when, in addition to it, others were scarcely needed. But now, when the growth of the city requires the Palace, the kitchen of which covers almost as much ground as the International did, and demands as much water to supply it as was required to supply the old International; when in addition to the Palace, the Baldwin, Occidental, Grand, Lick, Russ, Cosmopolitan, Brooklyn, Commercial, and scores of other hotels are needed to accommodate the traveling public; when the city has extended its business streets from bay to ocean; when large and magnificent structures have been erected to accommodate the permanent business of the city – structures unequaled by few, and unsurpassed in no city in the United States; when its residence properties, having been extended miles and miles, containing homes which are palaces, and comparing favorably with the residences accorded to royalty in foreign countries; with our parks opened and beautified, demanding more water in a day than was formerly supplied by the Ensign & Bensley companies in a year for similar purposes; with large public institutions now existing, requiring more water in a day than Spring Valley five years ago furnished to the combined hotels of the town —in view of these facts, and the future, we think this "City System of Distribution" should be pronounced inadequate and insufficient.

We do not mean to say that Spring Valley has not a few miles of pipe in its service system which will be available within ten years; but we assert that if this City shall continue to advance the next ten years as it has during the last ten, that Spring Valley has but few miles of pipe which will not require removal and replacement by new mains and distributing pipes of larger capacity.

When, then, we are confronted with the "Service System," we say to the Commission, give us an idea of what the City will need by the time we can construct our works, and we will give you an estimate, and security for its performance.

"PENINSULA SUPPLIES."

We have had careful surveys and calculations made by our engineers relative to the Peninsula supplies, and we designed presenting the results to the Commission, but on the 2d day of May, 1877, there appeared an exhaustive article in the *San Francisco Daily Chronicle*, which we have been informed was compiled by an engineer not connected with or employed by any one of the representatives of the various water schemes presented before the Commission.

On an examination of the article by us, it was found to be so thorough and to agree so perfectly with the opinion entertained by our engineers, that in order to detail them for other duties and to save valuable time we incorporate it as a part of our statement and append it as an exhibit.

An examination of these sources suggusted to us the potential fact that the City and County of San Francisco needs absolutely and immediately a source of supply which can be speedily made available.

While our Company has no interest, direct or indirect, immediate or remote, probable or possible, with any other proposition submitted to the Commission; and above every one insist that the plans it presents are the most feasible and practicable for the future wants of the City, yet we feel in duty bound to present to the Commissioners the fact that in view of another year of drouth succeeding the one last past, and in view or the daily necessities of the City for water for its parks, for fires, for the cleanliness of its sewers and streets,

and for the general good health of its citizens and protection of private and public properties, that a source of supply which can be made available immediately should be obtained by the Commissioners.

That such supply does exist we have the frankness to admit, and whether or not it injures our Company, yet we urge that the waters of Laguna de la Merced should be purchased, and means taken immediately to introduce the water thereof into this City.

FINANCIAL SUGGESTION IN ANSWER TO THE FINANCIAL ARGUMENT OF SPRING VALLEY.

It is not necessary to the presentation and maintaining before your Honorable Body the merits of our plans and proposals that we should consume valuable time to you and ourselves by entering into an analysis or a criticism of the many statements made to your Honorable Body by the Spring Valley Water Company. There is one statement, however, that we do not propose shall pass unnoticed. You have been already told by this Company of the heavy financial burdens to be certainly borne in the future by the people of San Francisco in the event that your Commission should select any sources of water supply other than those of the Spring Valley Water Company. Now we aver that such statements and conclusions are errors of fact, which we undertake to prove from their own books and figures, which speak for themselves.

On page 111 of Scowden's Report, the Secretary of the Spring Valley Water Company, in submitting his annual Report to the President of said Company, Mr. Howard, states that the receipts of said Company from Water Rents from June, 1874, to June, 1875, amounted to the sum of $1,090,634.18. Now these Water Rents are paid monthly in advance, or at the end of each month, which fact makes said sum at its added value, with interest at six per cent. per annum, equal to $1,120,811.

Assuming, then, that the city should select a new source of water supply costing $14,000,-000, to be paid in 30-year bonds bearing interest at the rate of six per cent. per annum, the interest thereon would be $840,000 annually. That is, the difference annually between the sum the people would have to pay in the future and that which they actually do now pay, is $280,811. Admitting that this difference would not increase, but remain a constant quantity (which is not the fact, for while the annual interest on the bonds would remain constant for 30 years. the water rents would increase annually in favor of the water company and against the people), and that if said difference was placed at interest at the rate of six per cent. per annum for 30 years, and this sum being an annuity, would at the end of said 30 years amount to the enormous sum of $23,813,200. An amount sufficient to constitute a sinking fund large enough not only to redeem the entire bonded debt, as proposed by the Feather River Water Company, but would leave also a balance ample to defray every expense likely to be incurred during said 30 years in connection with the new plan of obtaining a water supply. This statement we have tabulated, and recommend the results thus found to the consideration of your Honorable Body when you shall view the water question from a financial standpoint.

THE TUNNEL AT THE GOLDEN GATE.

This appeared to the company as the most difficult to solve of the problems with which it was confronted in the bringing of fresh, pure water to the City and County of San Francisco.

Anticipating that it would be asserted that such work could not be done, we have thought that the best answer that could possibly be given to the assertion would be the statement that the company promises to build and construct the tunnel at its own risk, and without asking a dollar of payment from the City and County of San Francisco until the said tunnel shall be built and constructed on either of the plans as will be hereafter presented by our engineers.

While recognizing this as the most potential answer that can be given to the assertions of impracticability, unfeasibility, and that the said tunnel cannot be constructed, yet for the satisfaction of the company, and for the satisfaction of the Commission and your distinguished engineer, Col. Mendell, we have obtained the following letter, signed by gentlemen distinguished in their professions and whose assertions are entitled to great weight and force, and certainly while not absolute as authority, can properly be declared as exceedingly persuasive to your Commission and your engineer, Col. Mendell.

The following is the written statement, the original of which we here furnish to the Commission:

VIRGINIA CITY, NEVADA, May 5th, 1877.

To GENERAL J. B. WINTERS,
President of the Feather River Water Company:

The question of tunneling the Golden Gate from Saucelito to Fort Point having been discussed with the public of San Francisco, and its feasibility and practicability having been doubted, we the undersigned give it our opinion that the project of tunneling the Golden Gate at said points is feasible and practicable, and that we would have no hesitancy of undertaking the construction of said tunnel, and at an expense that engineers of good standing in their profession should estimate.

We do not regard the said construction as more difficult, hazardous or expensive than works of a similar nature that we know have been constructed by the capital and engineering talent in the State of Nevada.

E. S. DAVIS,
United States Surveyor for Nevada.
JAMES BUTLER,
Chief Clerk Surveyor General's Office.
W. H. SMITH,
Superintendent Belcher Mine.
THOS. G. TAYLOR,
Superintendent Yellow Jacket S. M. Co.
SAM. T. CURTIS,
Superintendent Ophir, Savage, Mexican and Union.
J. B. OVERTON,
Superintendent Virginia and Gold Hill Water Co.
JAMES G. FAIR,
Superintendent Cal. and Consolidated Virginia M. Cos.
WM. H. PATTON,
Supervising Engineer Cal. and Consolidated Virginia M. Cos.

The names attached to this letter need no introduction to the public of San Francisco. It will be perceived that these gentlemen are willing to undertake the construction of said tunnel, and it can hardly be doubted that other gentlemen residing in the State of California will be found to undertake the work of construction which we have not thought or been advised was either hazardous or chimerical.

PROPOSALS.

The Feather River Water Company propose to the Honorable the Board of Water Commissioners the following:

FIRST.

To supply from the head-waters of Feather River—adopting either of the sources hereinbefore described—to construct the canal; to furnish the pipe required for the pipe line and to build and construct the tunnel; to furnish reservoirs in Bear Valley, Indian Valley, Up-

per Little High Valley, Lower Little High Valley, and a reservoir in the Sierras, and at or near Saucelito, in Marin County—furnishing a daily supply of

25,000,000 gallons	for the	sum of		$13,969,775
50,000,000	"	"	"	17,237,407
75,000,000	"	"	"	20,111,189
100,000,000	"	"	"	22,984,770

SECOND.

To supply from the waters of Stony and other creeks in the Coast Range—to construct the canal; to furnish necessary pipe and to build and construct the tunnel; to furnish reservoirs in Bear Valley, Indian Valley, Upper Little High Valley, and Lower Little High Valley, and a reservoir at or near Saucelito, in Marin County—furnishing a daily supply of

25,000,000 gallons	for the	sum of		$11,260,000
50,000,000	"	"	"	12,460,000
75,000,000	"	"	"	13,750,000
100,000,000	"	"	"	15,110,000

THIRD.

To supply from the waters of Stony and other creeks in the Coast Range—to construct the canal; to furnish the necessary pipe and to build and construct the tunnel; and to furnish reservoirs in Bear Valley, Indian Valley, Upper Little High Valley and Lower Little High Valley, and to take the waters of Puta Creek and to furnish reservoirs in Berryessa Valley and a reservoir at or near Saucelito, in Marin County—furnishing a daily supply of

25.000,000 gallons	for the	sum of		$12,250,000
50,000,000	"	"	"	14,000,000
75,000,000	"	"	"	15,500,000
100,000,000	"	"	"	17,000,000

FOURTH.

To supply from the head-waters of Eel River—to construct the canal; furnish the necessary pipe line and to build and construct the tunnel; to furnish reservoirs at suitable places along the canal line, to be selected by your Engineer, and a reservoir at or near Saucelito, in Marin County—furnishing a daily supply of

25,000,000 gallons	for the	sum of		$10.150,000
50,000,000	"	"	"	11,250,000
75,000,000	"	"	"	13,000,000
100,000,000	"	"	"	15,000,000

FIFTH.

To supply from the head-waters of Puta Creek, with reservoirs in Berryessa Valley; to construct the canal; furnish the necessary pipe; to build and construct the tunnel; and to furnish a reservoir at or near Saucelito, in Marin County—furnishing a daily supply of

25,000,000 gallons	for the	sum of		$8,500,000 00
50,000,000	"	"	"	9,750,000 00
75,000,000	"	"	"	11,000,000 00
100,000,000	"	"	"	13,000,000 20

SIXTH.

To supply, from the head waters of Russian River, with reservoirs at different points along the route of the canal; to construct the canal; to furnish the necessary pipe; to build

and construct the tunnel; and to furnish a reservoir at or near Saucelito, in Marin County, furnishing a daily supply of

25,000,000 gallons for the sum of				$9,650,000
50,000,000	"	"	"	10,900,000
75,000,000	"	"	"	12,150,000
100,000,000	"	"	"	14,200,000

In each and all of these propositions it is to be understood that the main canals shall have a carrying capacity of one hundred millions gallons water daily.

TIME OF CONSTRUCTION.

We propose to construct the works in either of the proposals presented within three years from such period after the signing of the contract as may be determined upon between the Feather River Water Company and the Commissioners.

RESERVOIRS IN SAN FRANCISCO.

We propose, if the contract be awarded to the F. R. W. Co., to indicate to your Commission favorable sites for reservoirs on the Government Reserve, which the City and County of San Francisco can no doubt obtain from the Government of the United States without cost, and which can be constructed at moderate expense.

PAYMENT FOR THE WORK.

We propose that the shaft on the San Francisco side of the Golden Gate, the tunnel under the Golden Gate, and the shaft on the Marin side of the Golden Gate shall constitute one section; and that on the completion of the same there shall be paid the sum of $1,500,000.

Thereafter the work shall be paid for as it progresses. Estimates to be made monthly by the Engineer of the Commission, as hereafter to be agreed upon; and seventy-five (75) per cent. of such estimate to be paid monthly.

Payments to be made in bonds of the City and County of San Francisco, issued in sums of $1,000 each, with coupons for interest. Said bonds shall draw interest at the rate of six (6) per cent. per annum from the date of the issuance.

The principal of the bonds shall be made payable at a specified day to be named in said bonds, which shall be thirty (30) years after their date, at the office of the Treasurer of the City and County of San Francisco.

The interest on said bonds shall be payable semi-annually, on the first day of January and the first day of July of each year, at said Treasurer's office.

Both principal and interest shall be payable in gold coin of the United States of America.

Said bonds shall be issued, signed and registered as required by the Act of the Legislature authorizing their issuance.

KEEPING THE WORKS IN REPAIR.

One of the most serious objections urged against the adoption of any plan providing for bringing water into San Francisco is the fact that the city would be required to employ a large number of persons to watch the line of works, and a large number of workmen to keep the same in repair.

To successfully answer this objection, after mature deliberation upon this subject, our company propose that in the event the Commissioners award us the contract, and the people of the City and County of San Francisco ratify the same, to take the supply of water from the Feather River, at either of the points herein designated, it will undertake and obligate itself to keep all of the works in repair, to be constructed by it, exclusive of pipes, for the use of the surplus water which said works and reservoirs will afford, after the daily delivery to the city of the quantity agreed to be furnished by this company. In view of this proposition, we submit that the manner and method of construction should be left to the judgment of our engineers, following and conforming to general formula, furnished by Col. Mendell, the Engineer of the Commission, and the company offer to the Commissioners, if the contract is awarded and ratified, security in any reasonable amount for the faithful performance of this special obligation.

FEATHER RIVER WATER COMPANY.

By JOHN B. WINTERS, President.

JOHN MULLAN,
JOSEPH M. NOUGUES, } Counsel.